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S103 discovering science

Note that the times shown in the study plan overleaf do not include the time that you will need to answer questions on the DVD and the TMA, making use of the set book, watching the TV programme, attending sessions at your local centre or reflecting on what you have learned and how you have learned it. Some students have also commented that *our* estimates of the times needed for the study of the DVD-multimedia activities are likely to be low.

Study Guide for Block 2

The Earth's surface temperature is of great importance to us and to all life on Earth. In Block 2 we develop an understanding of what determines the Earth's surface temperature, why it has changed in the past, and why it will change in the future. The story is, at heart, a scientific story, and therefore in developing it we need to introduce a broad range of basic science. This science is essential for Block 2, but it is doubly worthwhile because much of it will provide a basis for the science developed in subsequent blocks.

The study plan overleaf gives estimates of the total times required for each section of the block. Of course, some sections may take you longer than the estimates here, and other sections may take less time. The time you need will depend largely on your familiarity with the scientific content, and on the extent to which you already have the various skills that are needed.

The study plan shows that Block 2 contains one practical activity, three DVD-video activities and the first two DVD-multimedia activities for the course, and the estimated times for each of these are also indicated to help with planning. The best time to do each activity is at the point that it is referred to in the book. The Study File notes for the practical activity (Activity 2.1 'Measuring precipitation') contain details of the equipment that you will need to provide: two collecting vessels, such as tin cans or plastic bottles, a (home-made) funnel, and a ruler. Activity 2.1 continues throughout your study of Block 2 and it is important that *you should make a start on it as early as possible in your first week of study*, though not before you have studied the preceding material in Section 2.

The DVD includes a series of 20 questions on Block 2 with which you can assess your understanding of the block material. These questions can be attempted any time after you have studied the relevant section — you don't need to wait to do all of them until after you have completed Block 2.

The tutor-marked assignment for this block (TMA 02) is your first full-length assignment and should be completed at the end of your study of Block 2, ideally within the four-week period. It is worth looking at the content of the TMA before you start your study of Block 2. Note that TMA questions are sometimes based around multimedia or practical activities. You should be aware of this before you attempt any activities that are assessed in a TMA.

The *Study Calendar* gives you the broadcast times of the relevant TV programme 'The science of climate'.

You had quite a lot of flexibility in scheduling your study of Block 1, but with Block 2 and subsequent blocks you will need to work to a more definite schedule. A four week period is allocated to studying Block 2 (see the *Study Calendar* for details), and definite periods are scheduled for all of the other blocks. It is important that you don't fall behind this schedule, and risk missing cut-off dates for assignments. You might consider starting to study Block 2 earlier than indicated in the *Study Calendar* to make sure that you keep ahead of the schedule!

We estimate that you will require a *minimum* of 10 hours of *directed* study each study week to study the main course materials. Because Block 2 is allocated four study weeks in the schedule, the estimated directed time to study all of the parts of Block 2 listed in the study plan overleaf is 40 hours. This study plan shows roughly how the sections of the block can be divided between the four weeks scheduled for Block 2 on this 10 hours per week basis, assuming that you work through the block at a steady rate.

You should start your study of Block 2 by reading Section 1 of the book. At the end of that section there is an activity that will help you to plan your study of Block 2.

5.1 DS/P

SUP 80861 5

2 A temperate Earth?

All study times are in hours*

Week	Sections of Block 2	Total study time	DVD-multimedia, DVD-video and practical activities
1	1 Introduction	½	
1	2 The Earth's surface temperature today and in the recent past	4½	practical work ½
1	3 The Earth's surface temperature in the distant past	3½	
1–2	4 What determines the Earth's GMST? Overview	2	
2	5 What determines the Earth's GMST? A closer look	5½	
2–3	6 The Earth's atmosphere	6½	video ½ video ¼ video ½
3	7 The water cycle	3½	
3–4	8 The carbon cycle	6	multimedia 1
4	9 Can we explain past variations in the GMST?	4	multimedia 1
4	10 The Earth's temperature in the future	3½	practical work ½
4	11 Summary and forward link	½	
	'The science of climate' should be viewed after you have completed Block 2		TV

*Times given here are to the nearest quarter hour. More precise times are given in the Study File notes. Note that the times for DVD-multimedia, DVD-video and practical work are included in the total time for the section in which they are studied.

TV

practical work

video DVD-video

multimedia DVD-multimedia

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Study File for Block 2

Contents

Notes on activities

The notes for each activity explain what you are required to do. They may also provide a table, grid or diagram to complete, or give guidance on how to tackle an activity. **It is, therefore, essential that you read through the notes before you attempt the activity. After completing the activity, study the relevant comments in the next section.**

No estimate of time is given for activities that should take 10 minutes or less.

In Block 1 all of the information for the skills development activities was provided in the book or the Study File. From Block 2 onwards you will make increasing use of *The Sciences Good Study Guide* (*SGSG*). We shall ask you to read sections of *SGSG* that are relevant to specific activities and, in addition, we shall provide references to sections of *SGSG* where you will find extra help, if you need it.

Activity 1.1 Planning your study of Block 2

(*The estimated time for this activity is 15 minutes.*)

(a) In Activity 7.1a of Block 1 you reflected on the need for planning, setting targets and finding time for study. You can now apply your conclusions from that activity to planning your study of Block 2.

First, look at your notes on Block 1 Activity 7.1a and then at our comments. (You may also wish to scan through *SGSG* Chapter 1, Section 3.) You may have identified that certain types of material took you longer to study than others. You will therefore want to get an overview of the variety of material in Block 2 so that you can make a better estimate of the time to allow for studying different parts of it. In Block 1 we introduced the technique of scanning, and you should use it now with Block 2: look at the contents list, glance at the section summaries and the boxes, and cast an eye over some of the figures. Also scan through this Study File and the objectives at the end. This process will give you an indication of how much material there is in Block 2, how much of it is new to you (probably most) and whether you need to allow more time for particular parts of it on the basis of your experience with Block 1.

The study plan on the Block 2 bookmark is a good starting point for planning the time you spend on the block. It shows how the practical work and DVD activities are distributed through the sections, gives the estimated time for each of these activities, and gives an estimate of the total time an 'average' student might require for each section.

5.1 DS

SUP 80856 9

The left-hand column shows roughly how far you should have reached at the end of each of the four study weeks.

You will need to plan when you will do TMA 02, the assignment related to Block 2, and the S103 Study Calendar gives the cut-off date. The Study Calendar also gives the transmission dates of the TV programme relevant to this block. You will have received the dates of the study sessions that your tutor will be holding at a local centre, and these also need to be included in your plan for Block 2.

We suggest that you plan your study of Block 2 using the grid below. You need to allocate time for each section (Sections 1–11), for each DVD-multimedia, DVD-video and practical activity shown on the bookmark and for doing the TMA.

	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
week 1	1·30 – 5·30	1 30 – 530	7:30 9·30		7·30 9·30	7 30 9 30	
week 2	"	"	"		"	"	
week 3	"	"	"		"	"	
week 4	"	"	"		"	"	

(b) In part (b) of Activity 7.1 in Block 1 you reviewed your progress with the techniques that we introduced for studying actively. We recommend that you look again at your notes on this activity and the decisions that you reached there before you start Section 2 of Block 2.

Activity 2.1 Measuring precipitation

Equipment

NON-KIT ITEMS
two collecting vessels
home-made funnel
dipstick and/or ruler
See 'Practical procedure' for further details.

(You need to spend about 1 hour in total on this activity, spread over three or four weeks, depending on when you start your study of Block 2.)

The results and design of this experiment may be tested in the TMA associated with Block 2, so it is worth looking at the assignment before you start this activity. Start by scanning through the following notes for this activity so that you can see how the work is distributed over the study period for Block 2. If you have started Block 2 ahead of time, you may be able to collect data over a four-week period; otherwise collecting data for three weeks during your study of Block 2 will be sufficient. You should complete the activity *before* the start of the study period for Block 3.

Aims

The main aim of this activity is to introduce you to the design of practical work, to making measurements, and to recording and analysing data. It should also help you to:

- understand how precipitation is measured;
- develop your understanding of the concept of a *mean*, introduced in Section 2.1;
- appreciate the uncertainties involved with measurements;
- appreciate the variability in quoted mean values.

Introduction

The activity involves constructing a rain gauge and measuring precipitation in order to calculate the mean daily precipitation over several weeks.

How precipitation is reported

Weather reports, such as that shown in Figure 2.1.1, report the amount of precipitation in units of length. Figure 2.1.1 gives the amount of precipitation in inches, but the more usual unit is millimetres. This may at first seem strange, because you might expect that the amount of rain, or other forms of precipitation, should be measured as a volume. However, what is being reported is the *depth* of rain that falls on the surface of the Earth in some location. Suppose we were to monitor the amount of rain that fell in one day on one square kilometre of a perfectly flat region of the Earth's surface, as shown in Figure 2.1.2. If we assume that the rain does not run off the surface and out of this area, that it is not absorbed into the ground, and that it does not evaporate, then we would get a pool of water with an area of one square kilometre (1 km^2). The depth of this pool would be a measure of the amount of rain that fell on that area in one day.

AROUND BRITAIN YESTERDAY

24 hrs to 5 pm: b=bright; c=cloud; d=drizzle; ds=dust storm; du=dull; f=fair; fg=fog; g=gale; h=hail; r=rain; sh=shower; sl=sleet; sn=snow; s=sun; t=thunder

	Sun hrs	Rain in	Max C	Max F			Sun hrs	Rain in	Max C	Max F	
Aberdeen	6.8	0.07	16	61	s	Lerwick	7.6	0.04	12	54	sh
Anglesey	7.1	0.04	15	59	s	Leuchars	8.8	0.01	16	61	s
Aspatria	X					Littlehmptn	6.0	0.10	20	68	sh
Aviemore	6.7	0.09	12	54	sh	London	5.7	0.12	18	64	sh
Belfast	6.0	0.26	12	54	sh	Lowestoft	7.8	0.21	20	68	r
Birmingham	5.5	0.01	17	63	sh	Manchester	4.2	0.13	15	59	sh
Bognor R	5.6	0.17	20	68	sh	Margate	7.9	0.06	21	70	sh
Bournem'th	6.4	0.06	19	66	sh	Minehead	5.8	0.03	16	61	b
Bristol	6.0	0.28	17	63	s	Morecambe	6.0	0.48	15	59	t
Buxton	4.6	0.31	12	54	s	Newcastle	5.4	0.23	14	57	sh
Cardiff	5.5	0.51	16	61	sh	Newquay	3.0	0.14	15	59	c
Clacton	7.9	0.14	17	63	sh	Norwich	X				
Cleethorpes	5.3	0.18	17	63	sh	Oxford	4.0	0.06	17	63	sh
Colwyn Bay	6.6	0.11	15	59	s	Penzance	X	0.09	17	63	s
Cromer	5.8	0.05	18	64	sh	Poole	5.4	0.05	21	70	sh

Figure 2.1.1 Part of a weather report from *The Times*, 13 September 1997.

- Assuming that the rain fell *uniformly* over the one square kilometre, would the depth of rainfall be any different if we were to measure it over (a) one square metre or (b) a circle 10 cm across?

- We would be looking at smaller pools with very different volumes of water, but in each case the depth would be the same, as shown in Figure 2.1.2.

So by quoting the precipitation as a depth, in millimetres, say, we get a measure of the amount of water that has fallen in a particular region, and this measure is independent of the size of the area on which the water has fallen.

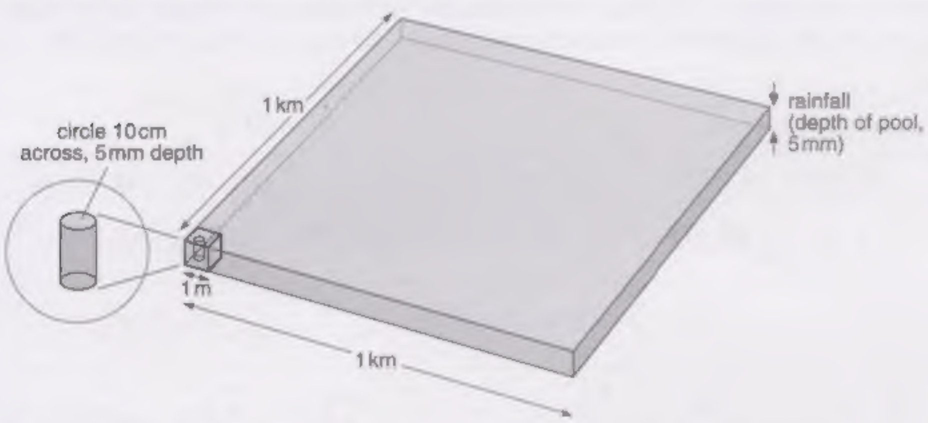


Figure 2.1.2 Pools of one square kilometre, one square metre, and a circle 10 cm across, containing water to a depth of 5 mm (not to scale).

Practical procedure

Task 1 Thinking about design

Spend a few minutes thinking about how you will measure the mean daily precipitation over three or four weeks. You should consider each of the following questions before looking at the discussion given in the comments on this activity.

- What type of collecting vessel will you use for the rain gauge? Should it have a particular size and shape? Does it need some form of cover?

- Where will you site the rain gauge?
- How will you measure the amount of precipitation?
- How often will you record the data? Should you empty the rain gauge after each measurement?
- What problems might you have in measuring the precipitation?

You should now look at the comments on this task before continuing with the activity.

Task 2 Constructing the rain gauges

You should now construct two rain gauges: one using an open-topped, straight-sided, flat-bottomed container — Gauge 1, and the second with a funnel in the top — Gauge 2. Tin cans and plastic bottles are useful construction materials, and the tops of plastic bottles are ideal for funnels. Figure 2.1.5 in the comments shows examples of simple home-made gauges, but you should feel free to use different designs if you wish. The use of two different rain gauges will demonstrate whether evaporation losses are significant.

Why should the area of the mouth of the funnel of Gauge 2 match the area of the bottom of the vessel?

The rain gauge collects water over an area defined by the mouth of the funnel, and so you need to measure the depth of a pool of water that matches this area.

Must the two rain gauges have the same area?

No. As we mentioned earlier, the depth of the precipitation is the same irrespective of the area that you choose for the measurement — provided that the area of the mouth of the rain gauge matches the area of the base.

Having constructed your gauges, you should set them up in your chosen location. You are now ready to start collecting data.

Results: week 1

Task 3 Obtaining the data

If possible, for the first week you should record the amount of precipitation each day over the previous 24 hours. The best way to do this is to measure the depths of the water in the two rain gauges each day at a particular time, to within a few minutes. Record your readings for the depths for seven consecutive days in the third and fifth rows of Table 2.1.1.

Table 2.1.1 Precipitation measurements each day for a week. 1.1

Date	7/02/07	8/02/07	9/02/07	10/02/07	11/02/07	12/02/07	13/02/07
Time of recording	19:30	19:30	19:30	19:30	19:30	19:30	19:30
Depth in Gauge 1/mm FUNNEL	0	1mm	7mm	1.9cm	1.9cm	2.6cm	3.1
Precipitation in previous 24 hours from Gauge 1/mm FUNNEL		1mm	6mm	12mm	0	7mm	5mm
Depth in Gauge 2/mm	0	1mm	11mm	21mm	21mm	3.2cm	3.~~4~~7
Precipitation in previous 24 hours from Gauge 2/mm		1mm	10mm	10mm	0	11mm	5mm

1.4

Gauge 1: mean daily precipitation for week 1 ....

Gauge 2: mean daily precipitation for week 1 ....

Analysis of results (at the end of week 1)

Task 4 The mean daily precipitation for week 1

Use your data in Table 2.1.1 to calculate the precipitation for each day measured by the two rain gauges (see the comments on Task 1), and enter these values in the fourth and sixth rows of the table. Then calculate the mean daily precipitation in your neighbourhood for week 1 for each gauge and enter the values below the table. (The method of calculating the mean is exactly the same as you used for calculating the mean surface temperature in Section 2.1.)

Uncertainties in the measurements

As we discussed in Block 2 Box 2.1, scientists generally quote the uncertainties associated with their measurements. In this experiment, unless there has been heavy rainfall, the depths of water that you measure each day in the first week will be rather small. Because you can probably measure the depth to only the nearest millimetre, your results will not be particularly precise. For example, you may have measured the depth of water in the rain gauge as 4 mm, to the nearest millimetre.

- How would you express the uncertainty in this depth?

- Measuring the depth to the nearest millimetre means that it could be anywhere between 3.5 mm and 4.5 mm. So the uncertainty is ± 0.5 mm, and you would quote this result as 4 mm ± 0.5 mm, as we discussed in Box 2.1.

So the uncertainty in each of your *daily* values of precipitation is about ± 0.5 mm. However, you have determined the *mean* daily precipitation by adding values of precipitation for seven days and dividing the total by seven. This total precipitation must be the same as the value measured on the seventh day, and the uncertainty in this value will be ± 0.5 mm. So if the total precipitation for the week were 20 mm ± 0.5 mm, then the mean daily precipitation would be $\frac{20}{7}$ mm ± $\frac{0.5}{7}$ mm, which is 2.857 1 mm ± 0.071 4 mm. Now clearly we are not justified in quoting all of these decimal places, and in practice scientists would quote this result as 2.9 mm ± 0.1 mm. Note that there are the same number of significant figures in the answer here as in the value of the weekly precipitation. So the uncertainty in the value of the mean daily precipitation is about ± 0.1 mm. Note that this uncertainty is less than the uncertainty in the measurement for a single day, and this is one reason for calculating a mean daily value from the precipitation for a week.

- You are trying to obtain a representative value for the mean daily precipitation, but what if there's no precipitation during the first week in which you are attempting to make measurements? What advantage is there in measuring the average over a longer period?

- The weather can be particularly variable in the short term. By measuring over a longer period you smooth out the occasional dry spell or wet spell so that your mean value is more representative of normal conditions.

Now look at the comments on Task 4 before continuing with this activity.

Results: weeks 2 and 3 (and 4)

Task 5 Obtaining the data

For the remaining two weeks (or three if you have time) we suggest that you just measure the water level once a week at the end of each week. Make the measurements at the same time used for the daily measurements in week 1 and record your results in Table 2.1.2. You should transfer the value for the first week's precipitation from Table 2.1.1 to the first empty column of Table 2.1.2.

Analysis of results (at the end of Section 10)

Task 6 The mean daily precipitation over three (or four) weeks

Use your data for Gauge 1 and for Gauge 2 in Table 2.1.2 to calculate two values of the mean daily precipitation for your neighbourhood for each of the weeks in which you measured the precipitation. Enter these values in the appropriate rows of the table. Then

calculate a mean daily precipitation for each gauge for the complete period, and enter these values below the table.

Table 2.1.2 Precipitation measurements each week for three or four weeks.

Date		W 2		
Time of recording		19:30		
Depth in Gauge 1/mm FUNNEL		4.5		
Precipitation in previous week from Gauge 1/mm		3.1		
Mean daily precipitation for the week from Gauge 1/mm				
Depth in Gauge 2/mm		5.6		
Precipitation in previous week from Gauge 2/mm		3.7		
Mean daily precipitation for the week from Gauge 2/mm				

Gauge 1: mean daily precipitation for the complete period ....

Gauge 2: mean daily precipitation for the complete period ....

Review

Task 7 Comparing the results from the two rain gauges

Was there any difference in the mean daily precipitation measured by the two rain gauges? If so, can you account for the difference? Did you remember to incude the units in your answer?

Task 8 Comparing your results with published data

Calculate the mean monthly precipitation from your results by multiplying the value obtained for Gauge 2 (in Task 6) by the number of days in the month (use the month in which you took most data). Figure 2.1.3 shows a map of the mean monthly precipitation in February for the UK. These data were obtained over a 30-year period. *If you are a UK resident*, locate on the map the area in which you live, and identify the mean monthly precipitation for February. Compare with your data. If you did the experiment in February, did you find your value for precipitation to be higher or lower than the February 30-year mean? If you did the experiment in October, does there appear to be more or less precipitation than in February? *If you are not a UK resident*, are your data comparable in magnitude with the precipitation in February in any particular region(s) in the UK?

Conclusion

A conclusion to an experiment is a succinct (three or four sentences) statement of the outcome of an experiment and how it fits in with or develops our present understanding of a phenomenon.

Task 9 Writing a conclusion for the experiment

Now write a conclusion for this experiment.

Task 10 Reflection on the practical work

(a) We posed various questions at the start of these notes to get you thinking about how you would carry out the experiment. Did you find that answering these questions was helpful in deciding how you would carry out the experiment? Can you think of ways of adapting this 'answering questions' approach to other practical work or problem solving where you aren't presented with a list of questions?

(b) Scientists often present their work in standard formats, and these notes for the rain gauge practical work follow a standard pattern. Quickly scan through the notes again,

noting the headings that have been used and the content of the sections that follow the headings. In later practical work we shall ask you to present your results in this way.

Now look at the rest of the comments on this activity.

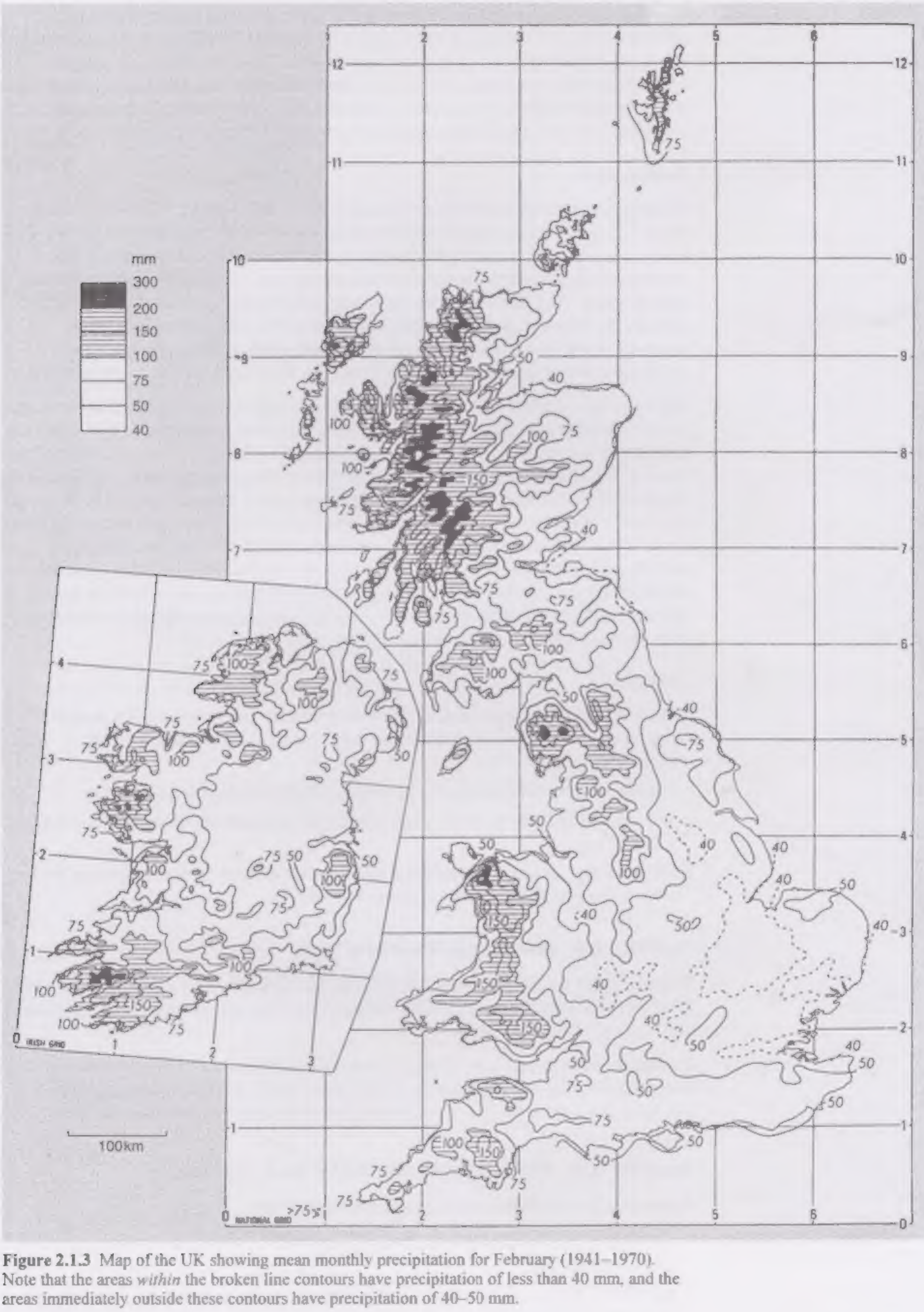


Figure 2.1.3 Map of the UK showing mean monthly precipitation for February (1941–1970). Note that the areas *within* the broken line contours have precipitation of less than 40 mm, and the areas immediately outside these contours have precipitation of 40–50 mm.

Activity 3.1 Summarizing the use of pollen diagrams

(*The estimated time for this activity is 20 minutes.*)

This activity asks you to summarize a section of the book text. Doing this will help you to consolidate your understanding of the text and also give you useful practice in tackling the type of writing task that is typical of those set in tutor-marked assignments. This is the first of three activities of this type in Block 2, so we offer some general advice here before specifying Activity 3.1. Advice on extracting information from a text and on writing has already been given in Block 1 (Sections 5 and 6 and the related activities). You may also find it useful to refer to *SGSG* Chapter 9, Section 3, now.

General advice

Examine the text to be summarized. If you have been following our suggestions from Block 1, then you will already have highlighted key words and phrases in some way. If not, you should go back and highlight them in the context of the particular activity. Exclude words, phrases and sentences that are peripheral, or that only add detail to the main message. Then make notes on a separate piece of paper. Review your notes and consider the most logical order for presenting them. For a short summary a single paragraph might be appropriate, though you should check whether your notes can be divided into two or three topics, in which case two or three paragraphs might be better.

Write your first draft of the summary. Try to do this without referring to the book so that you are more likely to express your answer using your own words. Check if its length is close to that asked for. If the draft is too long, consider whether you have included some minor points of detail that can be dropped or if your writing can be more concise and to the point. If, on the other hand, your first draft is too short, then perhaps you have missed out some vital points, or perhaps you have been *too* concise, resulting in rather disjointed prose, all too apparent when you read it out aloud. You should also check that the spelling and punctuation are correct. Several drafts may be necessary before you feel satisfied with your summary. You should go back and check the main points in the text before finalizing your summary, and then carefully compare your summary with the one given in the comments on the activity.

Activity 3.1

Summarize in your own words how pollen diagrams are used to reconstruct ancient temperature records. You should aim at a single paragraph of about 150 words, structured as follows:

- explain what a pollen diagram is, by writing a definition in your own words;
- explain why the information displayed on a pollen diagram provides insight into past climate;
- illustrate the types of result obtained from a pollen diagram by referring to any feature seen in the Grande Pile pollen diagram (Figure 3.14).

Activity 4.1 Modifying the leaky tank

With the aid of Figure 4.3 in Block 2, describe what happens to an initially steady water level when the rate of water flow from the tap is constant, but the rectangular slot is: (a) narrowed; (b) opened wider.

Your description in each case should consist of several sentences, plus diagrams showing the tank at the start and finish, and a sketch graph (similar in style to those in Figure 4.3 but without any values on the axes) showing how the water level changes with time.

Activity 4.2 Summarizing the leaky tank analogy

Summarize how the leaky tank analogy demonstrates that:

- the GMST does not change if the rate of energy gain by the Earth's surface equals the rate of energy loss;
- the GMST starts to change immediately following a change in the rate of energy gain or the rate of energy loss.

Section 4.1.1 contains the material to be summarized. Reread this section and identify the relevant paragraphs. Within these paragraphs highlight the key words and phrases if you have not done so already. Then make notes and, if necessary, reorder them to give a logical flow

This is the first of several activities in Block 2 that ask you to summarize a section of text, but do not require you to write your answer as a structured piece of writing. The purpose of these activities is to make sure that you have understood what you have read, and you will probably find it easier to leave your answer in note form. This is all that we are expecting you to do here. However, if as a result of studying Block 1 and doing Activity 3.1 in this block, you feel that you need more practice at writing, then you can of course try writing your notes as continuous prose. If you do so on this occasion you should aim to write your answer in 100–150 words. In the comments on this activity we have given two answers; one in note form and one as more structured prose.

Activity 5.1 Radiant heating of light and dark surfaces

(*The estimated time for this activity is 45 minutes.*)

In this activity you will investigate the approach to a steady-state temperature of two aluminium plates — one bare aluminium, the other coated black — heated by radiation (from a light bulb). You will do this by reading about an experiment and analysing the results from the experiment that two members of the course team have obtained. Their account is presented in the sections 'Practical procedure' and 'Results'.

This activity will reinforce the ideas that:

- a transfer of radiant energy can cause a rise in temperature;
- in a steady state there is no change of temperature, because the rate of gain of energy is equal to the rate of loss;
- the steady-state temperature of an object depends on the fraction of incident radiation reflected from it.

It will also develop some skills of data analysis, particularly graph plotting and interpreting experimental results

Before you begin, take a moment to think about what you might expect to happen. What everyday experience have you had of light and dark objects heating up in the Sun? What do you think might happen to the temperature of the bare, uncoated plate compared with the black-coated plate? Will the plates go on getting hotter and hotter and hotter? (Do you get hotter and hotter when you sit in front of a fire?)

Practical procedure

The apparatus used is shown in Figure 5.1.1. The two aluminium plates — one bare metal, the other coated black — were mounted side-by-side on an insulating base, with two similar thermometers just behind the plates. These thermometers measure temperatures in degrees Celsius (°C).

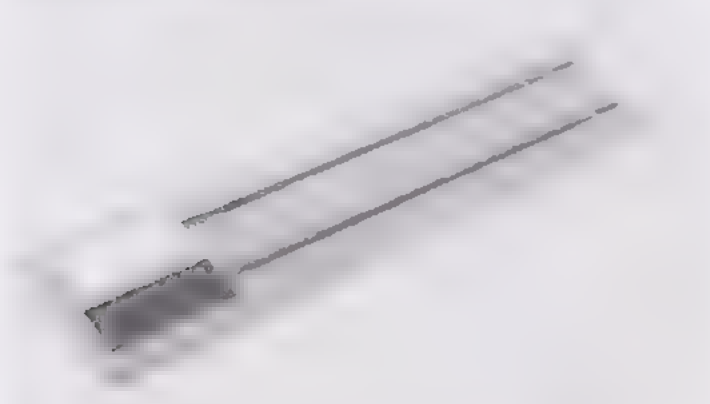


Figure 5.1.1 The two aluminium plates, on an insulating base, with thermometers behind each plate.

The plates were heated by an ordinary 60-watt light bulb mounted in a reading lamp, as shown in Figure 5.1.2. The plates were placed directly *below* the bulb so that heating by rising currents of warm air could play no part, and care was taken to ensure that the two plates were the same distance from the bulb — about 12 cm.

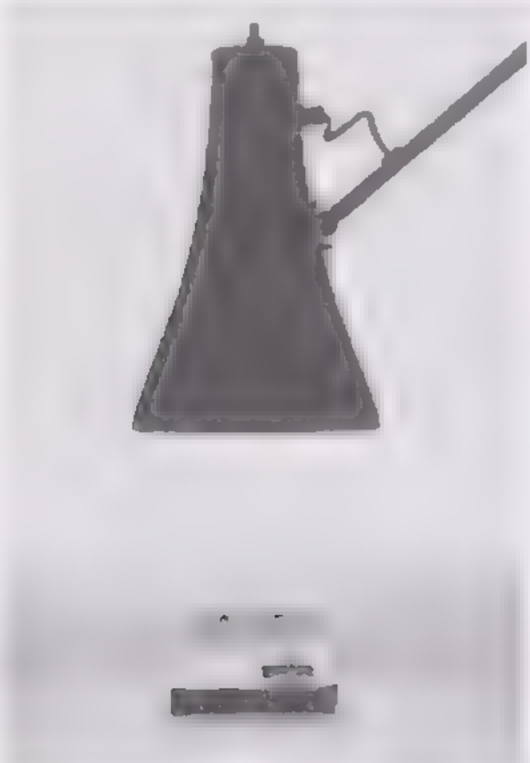


Figure 5.1.2 The plates being heated by a light bulb in a reading lamp

We set up the equipment in a darkened room so that the 60 W bulb was the only significant source of radiation when it was switched on. The room was free from draughts, and the room heating had been on at a constant level for some time: these precautions ensured that the plates could reach a steady state before the bulb was switched on, and that they could reach a *new* steady state some time after it was switched on.

Before we switched the lamp on, we read the temperatures of the two plates at five-minute intervals, and the values settled down to 18.5 °C, with less than 0.5 °C change over three consecutive readings. For our purposes the plates were then close enough to a steady state with the lamp off.

The lamp was then switched on and the radiation from it heated the plates. The plate temperatures were recorded after the lamp had been on for one minute (within a few seconds). We recorded values of the temperatures to the nearest half degree, and we estimated that the uncertainties in these temperatures were about ± 0.5 °C. We repeated the measurements at one-minute intervals until the plate temperatures were changing far more slowly than they were just after the lamp was switched on. The plates were then close enough to their new steady states, but this time with the lamp on. That completed the measurements.

Results

The temperatures of the two plates at one-minute intervals are recorded in Table 5.1.1. The lamp was switched on at the time of the first recorded temperatures, i.e. at a clock time of 26:00 (26 minutes, 0 seconds).

Task 1 Completing the temperature measurements

Figure 5.1.3 shows the thermometers at times within a few seconds of 34, 36 and 38 minutes clock time. Read the temperatures from the thermometers and record them in the appropriate gaps in Table 5.1.1.

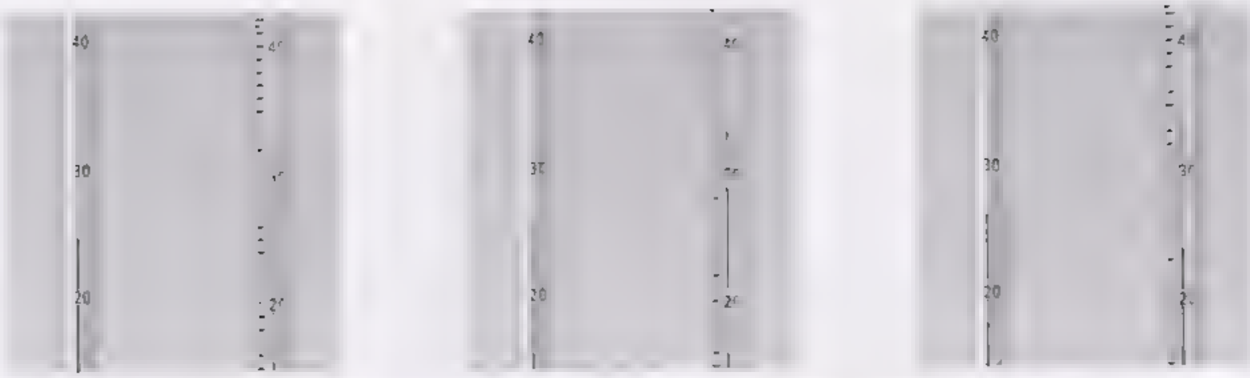


Figure 5.1.3 The thermometers at clock times of (a) 34 minutes, (b) 36 minutes and (c) 38 minutes. In each case the thermometer behind the uncoated plate is on the left.

Table 5.1.1 Results from the radiant heating experiment.

Clock time /minutes.seconds	Uncoated plate temperature/°C	Black-coated plate temperature/°C	Elapsed time since lamp switched on /minutes.seconds	Uncoated plate temperature increase/°C	Black-coated plate temperature increase/°C
26:00	18.5	18.5	0	0	0
27:00	19.0	20.0	1.00	0.5°C	1.5°C
28:00	20.0	22.0	2.00	1.5°C	3.5°C
29:00	20.5	24.5	3.00	2.0°C	6.0°C
30:00	21.5	26.5	4.00	3.0°C	8.0°C
31:00	22.5	28.0	5.00	4.0°C	9.5°C
32:00	23.0	30.0	6.00	4.5°C	11.5°C
33:00	24.0	31.0	7.00	5.5°C	12.5°C
34:00	24.5	32.0	8.00	6.0°C	13.5°C
35:00	25.0	33.0	9.00	6.5°C	14.5°C
36:00	25.5	33.5	10.00	7.0°C	15.0°C
37:00	26.0	34.0	11.00	7.5°C	15.5°C
38:00	26.0	34.5	12.00	7.5°C	16.0°C
39:00	26.5	35.0	13.00	8.0°C	16.5°C
40:00	26.5	35.0	14.00	8.0°C	16.5°C
41:00	27.0	35.5	15.00	8.5°C	17.0°C
42:00	27.0	36.0	16.00	8.5°C	17.5°C
43:00	27.0	36.0	17.00	8.5°C	17.5°C
44:00	27.5	36.0	18.00	9.0°C	17.5°C
45:00	27.5	36.0	19.00	9.0°C	17.5°C
46:00	27.5	36.0	20.00	9.0°C	17.5°C

Analysis of results

Task 2 Completing the table of data

For each of the rows of Table 5.1.1, calculate the number of minutes that elapsed between the lamp being switched on and the temperature readings being taken, and enter them in column 4. Then calculate the change in the temperature of each plate *since the lamp was switched on*, and enter the values in columns 5 and 6.

It is often easier to reach conclusions about numerical data from a graph than from a table of results, so your next task is to use the values that you have just calculated to plot graphs of temperature increase versus elapsed time for each plate. But *before* you plot these results, study Box 5.1.1, *Plotting points onto graph paper*.

Box 5.1.1 Plotting points onto graph paper

You have seen in Block 1 and in Sections 2 and 3 of this block that when you read from a graph you select the point of interest and move straight down from that point to the horizontal axis, and read off the value from the scale, as in Figure 5.1.4. Then, from the same point, you move straight across to the vertical axis, and read the value off that axis

For the point in Figure 5.1.4, what are the time and temperature increase?

The time (horizontal axis) is 15 minutes, and the temperature increase (vertical axis) is 11.0 °C.

Plotting a point on a graph is the reverse of reading from a graph. Suppose that you were given the values 15 minutes and 11.0 °C and had to plot them as a point on the graph in Figure 5.1.4. You would go along the horizontal axis until you came to 15 minutes — there happens to be a tick mark at 15. You would then draw a line straight up the page (in light pencil, so that you can rub it out afterwards). Next, you would find 11.0 °C on the vertical axis; clearly this must be a little way beyond the line that is marked 10. Since 5 °C corresponds to 25 divisions on this axis, 1 °C must correspond to five divisions, and so 11.0 °C is five divisions above the 10 °C line. You would therefore draw a line straight across the page here. The point where the vertical and horizontal lines intersect corresponds to a time of 15 minutes and a temperature of 11.0 °C. You then make a clear permanent mark at this point, such as a dot or a small cross. This procedure is repeated for all the pairs of values of time and temperature that you wish to plot. With a bit of experience at graph plotting, you'll find that you don't need to draw the vertical and horizontal lines to find the intersection point, provided that you are using graph paper

Task 3 Plotting a graph of the temperature changes versus time

You should now use the data that you have calculated in Table 5.1.1 to plot graphs of temperature increase versus elapsed time for each aluminium plate, using the graph paper in Figure 5.1.5. Note that the axes have been prepared for you: the time goes along the horizontal axis, and the temperature increase is along the vertical axis. It is a good idea to plot the points in pencil, in case of mistakes. Do this now, using dots for one plate and crosses for the other to distinguish the temperatures of the two plates.

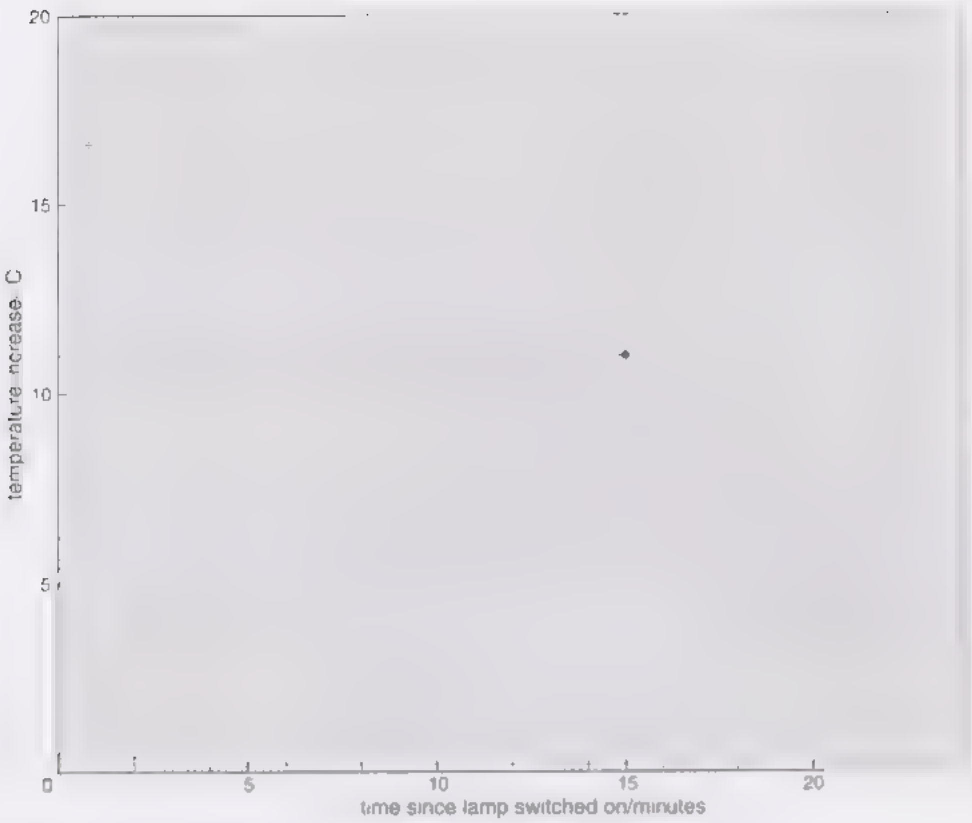


Figure 5.1.4 Reading and plotting a point on a graph

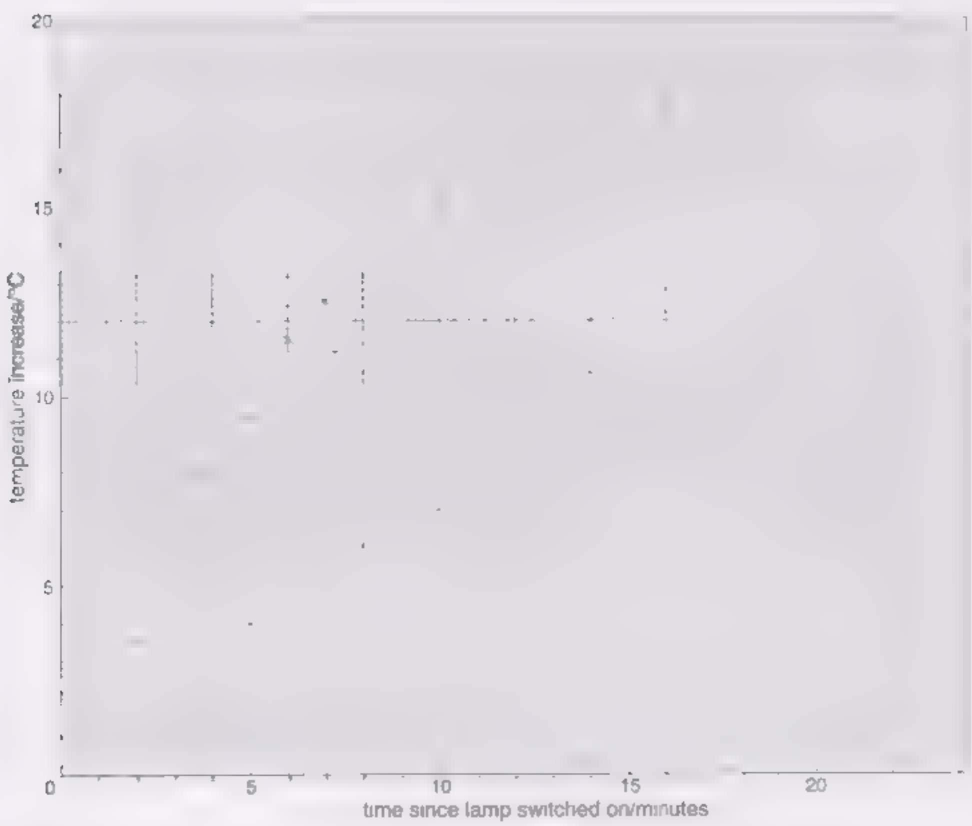


Figure 5.1.5 Prepared graph paper for plotting the increase in plate temperature versus elapsed time.

Task 4 Reviewing the results

Examine your graphs, and then answer the following questions.

(a) What happened to the plate temperatures when the bulb was switched on, and why?

(b) Did the two plates reach different temperatures? If so, why?

(c) Describe any evidence in your graphs that the plate temperatures approached a new steady state. Outline the physical process that led to the new steady state.

(d) If, towards the end of the measurements, the plate temperatures had been varying irregularly, or falling slightly, how would you account for this?

(e) What would happen if we were to repeat the experiment, with everything the same, except that we used a higher wattage bulb?

Task 5 Writing a conclusion for the experiment

To round off this activity, you should write a brief conclusion for the experiment. This should summarize in two or three sentences (or as a list two or three points) the main results of the experiment.

Activity 5.2 Alternative diagram of the rates of energy gain and loss by the Earth's surface and atmosphere

Figure 5.14 summarizes the energy flows that determine the Earth's GMST, as discussed in Section 5. Flow diagrams like this are a particularly useful way of summarizing information, and you had practice at producing such a diagram in Activity 6.2 of Block 1. You will meet many examples of flow diagrams throughout the course and you will develop further the skill of constructing your own flow diagrams. To develop your ability to use flow diagrams we want you to convert Figure 5.14 into a different form. To help you, the basic outline of the flow diagram has been drawn in Figure 5.2.1 as a set of lines connecting four boxes. The lines represent the energy transfers between the different boxes, and one of them has been labelled. Your task is to add the labels to the other lines. Try to do this at first *without* referring to Figure 5.14.

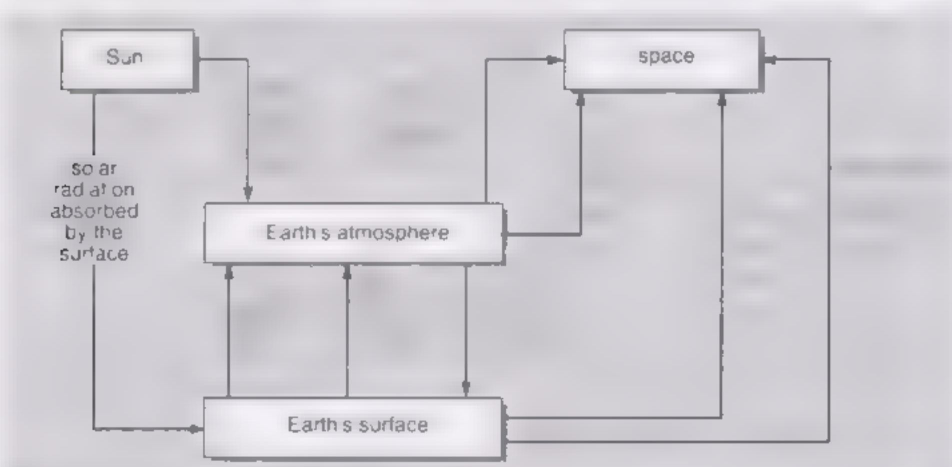


Figure 5.2.1 A partially redrawn version of Block 2 Figure 5.14

Activity 5.3 Energy balance diagram for the Moon

Here are some properties of the Moon.

- It is in orbit around the Earth and so the average distance from the Moon to the Sun is the same as that from the Earth to the Sun.
- Its surface area is only about 7% of the Earth's surface area.
- It has no atmosphere.
- The only significant source of energy for its surface is solar radiation
- Its surface reflects 8% of the solar radiation that it intercepts
- Its global mean surface temperature is not changing (and happens to be 1 °C)

(a) Draw the overall energy balance diagram for the Moon, i.e. the lunar version of Figure 5.14. Use 100 units to represent the rate at which solar radiation is intercepted by the Moon.

(b) 100 units do not correspond to the same number of watts as the 100 units in Figure 5.14. Why not?

(c) Describe, in a sentence or two, what each of the arrows in your diagram represents, and justify the number of units that you place on each arrow.

(d) Describe how the lunar surface would adjust to a new temperature if, somehow:

(i) the lunar surface became more highly reflecting to solar radiation, with no change in its infrared properties;

(ii) the Moon acquired an atmosphere that was transparent to solar radiation, but absorbed a large fraction of longwave infrared radiation.

Activity 5.4 Review of progress

(*You should spend no more than 15 minutes on this activity*)

From the start of Block 1 you have been asked periodically to think about how well you are learning from the course material Activity 7.1 in Block 1 particularly focused on this. As you worked through the first five sections of Block 2, the science has become more challenging and so this is a good time to review how well your learning is going.

(a) Look at the study plan you drew up in Activity 1.1. Are you abreast of your plan, ahead of it, or behind it? Scan through the remaining sections of Block 2, as we recommended in Activity 1.1, and make any revisions to your study plan that might be necessary. If you are seriously behind then you might have underestimated the time that you need to study this block. Can you allocate more time?

(b) You also need to consider whether you have been using your time effectively. This means more than just keeping to a schedule (and that can be difficult enough, as you have probably found out). Answering the following questions will help you to review how effectively you are studying.

(i) Identify a part of Block 2 where you feel your learning went really well. Why did it go so well? Was it because of the type of material, because of the time of day you were studying, or because you were feeling particularly fresh?

(ii) Identify a part of Block 2 where you feel your learning went badly. Why do you think it went badly? Again, was it the type of material, because you were tired, or because you kept being interrupted?

(c) As you study the S103 blocks we encourage you to interact with the text by highlighting, making notes, summarizing and representing text in the form of diagrams, explaining things in your own words, and so on. We call this 'active reading' because it is so very different from sitting passively reading a textbook. Some of the activities are specifically designed to help you to do this.

- Have you found these activities useful, or did you think that they were a waste of time?
- Have you been reading actively?
- Has this helped you to understand the material?

Reflect on these issues, and then look at the comments on this activity.

If you have not yet tried the questions for Sections 2 to 5 on the Block 2 DVD, now would be a good time to attempt them. To start, you need to open the DVD Multimedia Guide and click on the Block 2 Questions button in the Block 2 folder

Activity 6.1 Composition and properties of air

Before you start learning about a new topic it can be useful to review what you already know about it, and so before you study the rest of Section 6 we want you to make a list of what you already know about the composition and properties of air. A good way to do this is to make two lists, one headed 'Composition' and the other 'Properties'. You may know something about what air is composed of from school or general knowledge, and you could think about what you and other living organisms need to survive. To think of properties, it may help to observe the world around you and to consider what is affected by the air.

As you are making these lists, you will probably find that various questions about the air spring to mind. Make a note of these questions; it is likely many of them will be answered as you study Section 6.

Activity 6.2 Evidence that air has substance

(The estimated time for this activity is 30 minutes.)

Learning from DVD-video

You have already studied some DVD-video activities in Block 1, but those were rather different from those in the rest of the course. We shall use DVD-videos mainly to show experiments and demonstrations, to illustrate dynamic phenomena through graphics and animations, and to explore various field locations. There are notes in the Study File for each DVD-video activity, and you should make sure that you read them carefully *before* you start to watch the DVD-video. The notes will tell you about any additional items that you need to have at hand when watching the DVD-video, but it is always useful to have a pen and paper with you so that you can make notes.

Some DVD-video activities require you to stop at a specific point and do something, such as a calculation. Don't be tempted to move on without doing the task; by carrying it out at that specific point you will be completing important steps in the activity and reinforcing your understanding.

We recommend that you make good use of replay facilities. If you don't understand a particular part of a sequence, or have a lapse in concentration, go back and watch that part again. Some DVD-video activities rely on a careful development of ideas and, if you miss an important point, you may lose track of the argument. Generally, you should find it useful to watch for a second time, to consolidate the ideas developed. When you have finished watching, check if there are any further tasks related to the activity and read any comments in the 'Comments' section of the Study File. Finally, you should remember to file your notes on the activity with the printed notes in the Study File.

Introduction to Activity 6.2

Suppose you were challenged to provide evidence to another student that the air has substance. What examples could you give of observations and measurements that indicate that the air is more than just empty space?

Some examples of evidence are shown in the Block 2 DVD-video 'Does the air have substance?'. The video shows a number of demonstrations, some of which support the hypothesis that the air has substance and some that are not relevant. As you watch these demonstrations, you should decide, and note down in Table 6.2.1, which of them provide good evidence that the air has substance, which do not, and which are irrelevant. You should give reasons for your answers. You will probably need to pause the DVD-video after each demonstration to make notes in the table. It will help you to note down in column 1 a brief description of the demonstration.

After watching the first part of the DVD-video and recording your conclusions, you should then watch the second part, in which the relevance of each demonstration is explained. You may wish to add comments to the table as you watch these explanations. You will need to use information from this table for a later activity, so make sure that your notes are clear.

'Does the air have substance?' is on DVD 1 (DVD-video sequence 99–127). You should view this now.

Table 6.2.1 Evidence that the air has substance.

	Demonstration	Evidence that air has substance? yes/no/irrelevant	Reasons for your answer
1	[illegible]	Yes	[illegible] This is [illegible] are moving must be helped to by something in the air
2	[illegible]	NO	It is the energy from the [illegible] the [illegible]
3	[illegible]	Yes	This [illegible] must contain something [illegible] in the air [illegible]
4	Bicycle pump	Yes	Air being pumped [illegible] air must have substance [illegible] air are [illegible]
5			[illegible]
6	Air in bottle	Yes	The [illegible] air must have substance
7	[illegible]	Yes	[illegible]

Activity 6.3 Active reading

(*You should spend no more than 20 minutes on this activity.*)

One way of making notes so that they convey information very quickly is to put them in the form of a diagram, and there is a good (if rather complicated) example of this in Figure 2.5 in Chapter 2, Section 5.2, of *SGSG*, which you should look at now. This is what is known as a 'spray diagram', and what the author has done is to summarize in the diagram the main points in the six-page article 'Food Poisoning' by Gerald Collee that is reproduced at the end of *SGSG*. But as well as summarizing neatly the main points, the diagram also indicates the relationship between them. Building up a spray diagram like this involves identifying the topics or themes and how they relate to each other, and this is a very effective way of learning the material.

Before constructing your own spray diagram it is useful to learn how to read an existing diagram, such as Figure 2.5 in *SGSG*. The important thing is to start from the right point, which is generally the centre of the spider's web, and to follow paths away from this point. So in Figure 2.5 of *SGSG* the starting point just gives title, author, etc., for the article that is being summarized. The six 'boxes' around the centre represent the key strands in the article, and following any one path out from the centre gives information on this particular strand. The order in which you read the different paths is somewhat arbitrary, but if in doubt start at '1 o'clock' and work your way round in a clockwise direction. So this first path could be read as 'Food poisoning is not necessarily poison in food; micro-organisms are the primary cause, and either they infect us, then poison us, or

they poison our food; in favourable conditions (when they have food, water and warmth) there is extremely rapid growth in numbers.'

Now we wouldn't necessarily expect you to understand all of this diagram without reading the article; the important thing is to read along a path moving away from the centre, because this is the direction of the logical flow of the points. Generally, where the path branches it doesn't matter in which order you follow the paths, though you need to be systematic so that you don't miss anything out.

Constructing a spray diagram for yourself is a bit more difficult than reading one. You start with the main topic in the centre of the page, and then draw lines out to the major subtopics, and lines from each subtopic to sub-subtopics, and so on. Sometimes you may want to identify all of the subtopics and draw them in before doing the sub-subtopics, but sometimes it is easier to follow a path from subtopic to sub-subtopic out to the end of that path before you start on the next subtopic. You may find it helpful initially to highlight the major points that will appear in a spray diagram before you start to construct it, but with practice you will be able to construct it as you read, particularly if the passage is well written and logically presented.

Producing a spray diagram to summarize Box 6.1 *Under pressure*

To give yourself some practice with this technique, try producing a spray diagram to summarize the contents of Box 6.1. If you haven't done so already, we suggest that you highlight the key points in the box before you start drawing your diagram. When you have completed the diagram, read through it, and then compare it with the examples in the comments on this activity.

video

Activity 6.4 The particle model

(*The estimated time for this activity is 20 minutes.*)

This DVD-video activity revisits the particle model, which was introduced in Section 6.1. It uses animations of the particle model to describe the make-up of solids, liquids and gases. It also describes, in a dynamic way, what happens at the particle level when a substance is heated and undergoes a change of state.

At the end of the sequence you are asked to predict what happens at the particle level when a gas is cooled to give a liquid and cooled further to give a solid. So, as the particle model of each state is described and the changes of state are explained, note down what happens so you will be able to answer the question at the end.

'The particle model' is on DVD 1 (DVD-video sequence 128–163). You should view this now. The answer to the question at the end of the sequence is in the comments on this activity.

Activity 6.5 Applying the particle model

(*The estimated time for this activity is 15 minutes.*)

Your completed version of Table 6.2.1 should contain enough information to remind you of the demonstrations in the DVD-video 'Does the air have substance?' For this activity, use the particle model to explain each of the demonstrations that showed that the air had substance, using two or three sentences for each. Start by trying to visualize what happens to the air particles in each demonstration. Ask yourself questions, such as 'what causes the phenomenon observed?', and 'how can this be explained with the particle model?'.

video

Activity 6.6 The composition of the atmosphere

(*The estimated time for this activity is 30 minutes.*)

This DVD-video describes the composition of the air, that is the various gases that make up the mixture we call air. As you watch it, make brief notes on the following:

- the gases that are present;
- the proportion of each gas in the air;
- the key properties of each gas – you don't need to list individual reactions here.

'The chemical composition of the air' is on DVD 1 (DVD-video sequence 164–224). You should view this now

In the DVD-video the composition of air is represented as a *pie chart*, rather than in a table like Table 6.2 in Block 2. This form of representation is explained in Box 6.6.1, *Numbers into pictures: pie charts.*

Box 6.6.1 Numbers into pictures: pie charts

Figure 6.6.1a shows a circular pie. If we divide the pie into four equal portions, as shown in Figure 6.6.1b, then each piece is $\frac{1}{4}$, or 25% of the whole pie.

- If we divide the pie into five equal portions, what percentage of the whole pie would each portion represent?

- Each portion would represent $\frac{1}{5} \times 100\%$, that is 20% of the whole pie.

Pie charts give a quick visual impression of the proportions that something is divided into; remember that the whole pie represents 100%.

We can represent the data in Block 2 Table 6.2 by a pie chart, as shown in Figure 6.6.2. Here the sizes of the portions reflect the percentage composition of the air, based on the numbers of particles of each gas in the atmosphere. Thus the whole pie (100%) represents the air, the largest segment (77.6%) represents the proportion of nitrogen, the next largest segment (20.9%) represents the proportion of oxygen, and so on.

Note that Figures 6.6.1c and 6.6.2 show two different ways of representing pie charts. The two-dimensional representation in Figure 6.6.1c shows the proportions more accurately than the three-dimensional representation in Figure 6.6.2, though the latter style is frequently used.

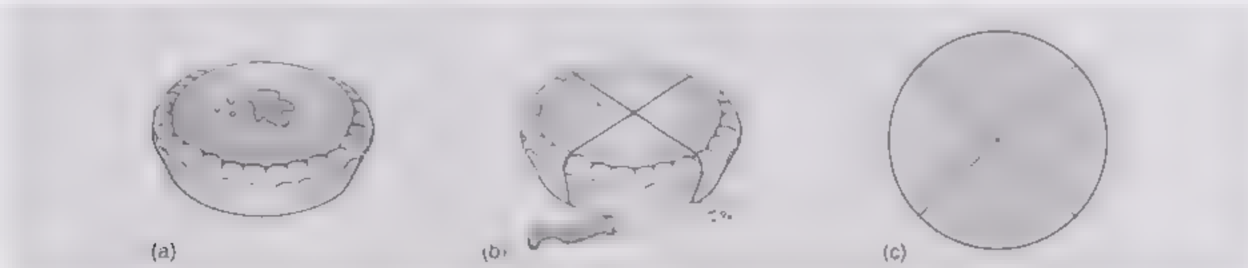


Figure 6.6.1 In a pie chart the whole pie is divided into segments, where the size of the segment reflects the proportion of the component it represents.

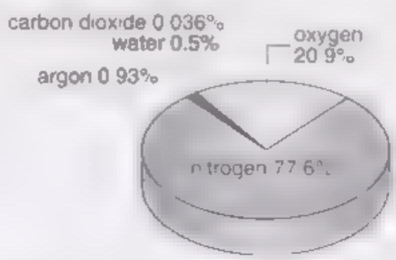


Figure 6.6.2 A pie chart showing the composition of the Earth's atmosphere. The sizes of the portions of pie are in proportion to the numbers of particles of the different components of the atmosphere. This is a different way of representing the information in the first two columns of Table 6.2 in Block 2.

Activity 6.7 Summary of the composition and properties of air

(*The estimated time for this activity is 15 minutes.*)

(a) Produce a list that summarizes what you now know about the properties of air, using a similar format to that used for Activity 6.1. We suggest that you do this from memory initially, and then scan through Section 6 to check that you have included all the important points.

(b) Compare your summary with the list that you produced for Activity 6.1.

(c) In Activity 6.1 we suggested that you make a note of any questions that you had about the air. Are any of your questions unanswered after studying Section 6? Have any new questions about the air occurred to you?

Activity 7.1 Feedback

Figure 7.1.1 shows a water tank with water entering the tank via a tap and leaving the tank via a pump. The rate at which water enters the tank remains constant but the rate at which water is pumped out of the tank depends on the level of water in the tank. At the start, the rate at which water enters the tank matches the rate at which it is pumped out, so that the level of water in the tank is constant.

(a) Describe what will happen when a bowl of water is added to the tank, if the rate at which the water is pumped out *increases* as the level of water in the tank gets higher. Is this an example of feedback, and if so, is it positive or negative feedback?

(b) Now assume that the rate at which the water is pumped out *decreases* as the level of water in the tank gets higher. Describe what will happen when a bowl of water is added to the tank, and explain whether this is positive or negative feedback.

Figure 7.1.1 A water tank where the rate at which water is pumped out depends on the level of water in the tank

Activity 8.1 Reservoirs of the global carbon cycle

Each of the seven reservoirs listed in Table 8.1 is in a steady state, so the rate of transfer of carbon into a reservoir is the same as the rate of transfer out of it. The rate of transfer of carbon out of a reservoir can be calculated from the following equation.

$$\text{rate of transfer of carbon} = \frac{\text{mass of carbon in reservoir}}{\text{residence time}} \qquad (8.1.1)$$

(If you compare this equation with Equation 7.1 for the residence time of water, you will see that similar quantities are involved in both equations, but whereas in Equation 7.1 we have an equation for calculating the residence time, in Equation 8.1.1 we have an equation for calculating the rate of transfer. Clearly these equations are closely related, and in Block 3 you will see exactly how.)

(a) Use Equation 8.1.1 to calculate the rate of transfer of carbon out of each of the seven reservoirs in Table 8.1. Express your answers to two significant figures, using the unit $10^{12}\,\mathrm{kg\,C\,y^{-1}}$, and enter them in the final column of Table 8.1.

(b) Write a sentence comparing the masses of the reservoirs and the rates of transfer of carbon in the biological subcycle with those in the geochemical subcycle.

Activity 8.2 Flow diagram of the global carbon cycle

In this activity you will produce your own flow diagram to represent the reservoirs involved in the carbon cycle and the rates of transfer of carbon between them. You'll do this in a number of stages, adding to the diagram as we discuss new reservoirs and transfer processes, so that by the end of Section 8.6 you will have a complete flow diagram for the global carbon cycle. At that point there will be an activity that requires you to identify each of the processes whereby carbon is transferred between the reservoirs To prepare for that activity, you might find it helpful to keep a list of the processes that correspond to the lettered arrows in Figure 8.2 and subsequent figures as you are introduced to these processes in the text.

Part I — to be done at the start of Section 8 4

(a) Use the information in Figure 8.2 to draw a flow diagram for the biological carbon cycle. Use four boxes for the four reservoirs shown, and arrows to represent the transfer of carbon between the reservoirs. (Don't worry about the positioning or shape of the boxes — there is no single 'right' way to do this.)

(b) Now, label each arrow with the appropriate letter and rate of transfer of carbon (from Figure 8.2), and confirm that, for all four boxes, the sum of the rates in equals the sum of the rates out. (You don't need to attach the unit $10^{12}\,\mathrm{kg\,C\,y^{-1}}$ to each rate of transfer provided that you note which unit you are using in the caption for your diagram, as in Figure 8.2.)

(c) Using the values in Table 8.1, enter the appropriate masses of carbon in the boxes representing the reservoirs. (Again, note the unit in the caption for your diagram)

Now look at the comments on this part of the activity

Part II — to be done at the end of Section 8 4 4

Make sure that you can name the processes that are responsible for the transfers of carbon represented by each of the arrows in Figure 8.2 and in your flow diagram. If you are unsure of which processes are involved, you should refer to the list that you have been compiling and then you should look back at the appropriate sections of the book.

There are no comments on Part II

Part III — to be done at the end of Section 8 5 1

Add a box labelled 'deep ocean' to your flow diagram, and add arrows to represent the rates of transfer of carbon between this reservoir and the surface ocean. Label the arrows with the appropriate letters and rates of transfer of carbon (from Figure 8.7), and insert the value (from Table 8.1) of the mass of carbon in the deep ocean reservoir in the appropriate box. Verify that this reservoir is in a steady state.

Now look at the comments on this part of the activity.

Part IV — to be done at the end of Section 8 6 2

(a) Add two final boxes representing the ocean sediment and rock reservoirs to your flow diagram, and draw in arrows to represent the transfer of carbon to and from these reservoirs. Label the boxes with the amounts of carbon stored in each reservoir (from Table 8.1), and label the arrows with the appropriate letters and rates of transfer of carbon (from Figure 8 7) Verify that these two reservoirs are in steady states

(b) Your flow diagram summarizes much of the information in Table 8.1 and in Figure 8.7. It includes information about the masses of carbon in each reservoir and the rates of transfer between them. What it doesn't show is the residence time for carbon in each reservoir, but this can be calculated from the information in the diagram. If we rewrite Equation 7.1 so that it applies to carbon rather than water, then we get

$$\text{residence time for carbon} = \frac{\text{mass of carbon in reservoir}}{\text{rate of transfer of carbon out of reservoir}} \qquad (8.2)$$

Use this equation to calculate the residence times for one or two of the reservoirs in Figure 8.2.3, and confirm that the values are the same as those given in Table 8.1.

Activity 8.3 Identifying processes for carbon transfer

(*The estimated time for this activity is 20 minutes.*)

(a) Match each of the arrows A to O in Figure 8.7 with one of the processes listed in Table 8.3.1. (Note that each process should be used only once. Some arrows may be matched by more than one process, and in these cases you should choose the process that best describes the transfer represented by the arrow.)

Table 8.3.1

Process	Arrow A–O	Carbon transformation
atmospheric CO_2 dissolution	F	Process by which CO_2 from the atmosphere dissolves into the surface seawater [illegible] dissolved carbon
biological pump		Particulate carbon is transported from surface ocean to deeper ocean
decomposition	D	In decomposition dead matter is [illegible] CO_2 [illegible] the atmosphere [illegible] by worms [illegible] bacteria etc
dissolution and respiration of sediment	K	The process by which carbonate carbon sediments and organic carbon sediment is transformed into dissolved carbon in the deep ocean
leaf fall and death	C	Process by which living organic carbon stored in vegetation is transferred to dead organic carbon to the soil either directly or via consumption by animals
CO_2 degassing	E	The process where dissolved carbon in surface seawater is released into atmosphere
photosynthesis		Through photosynthesis CO_2 in the atmosphere (or dissolved in water) is converted into organic carbon in green plants.
respiration	B	Food is broken down to simple [illegible] to release energy CO_2 created [illegible] process is [illegible]
rock formation (land)	M	Process in which deep-buried organic carbon is [illegible] (converted into organic rock)
rock formation (ocean)		Process by which organic carbon or carbonate in sediment is converted into organic sedimentary rock or carbonate rock
sedimentation	J	Process by which particulate carbon from the deep ocean is transferred to organic and carbonate sediments
sinking	H	Process in which dissolved carbon is transported [illegible]
upwelling	G	[illegible] from the [illegible] ocean [illegible] surface sea, [illegible]
volcanism	O	The [illegible] of rock [illegible] CO_2 and [illegible] into the atmosphere
weathering	N	The weathering of [illegible] rock by [illegible] and water releases organic carbon and carbonate [illegible] the surface ocean as dissolved carbon

(b) Carbon exists as different chemical compounds in different reservoirs and, in moving between reservoirs, it is often changed from one form into another. Describe, with a sentence for each, the major carbon *transformation* represented by each process listed in Table 8.3.1. For instance, you might say 'Through photosynthesis, CO_2 in the atmosphere (or dissolved in water) is converted into organic carbon in green plants.' Write your answers in Table 8.3.1.

Try to do this first without referring to the text. Then check your answers by looking at the book — your highlighting or notes should have picked out the important points — before comparing your list with the one in the comments on this activity.

Activity 8.4 Calculating increases in atmospheric CO_2

This activity will allow you to assess how the annual increase in atmospheric CO_2 compares with the rate of release of CO_2 to the atmosphere each year by human activity. It will also provide practice in analysing graphical and numerical information.

(a) Using Figure 8.9, determine the difference between the proportion of CO_2 (in p.p.m.) in the atmosphere in 1968 and that in 1992. (Use a value for each year that is the approximate mean of the high winter value and the low summer value.)

(b) Determine the mean increase per year during that time period. (Express your answer in p.p.m. $CO_2\,y^{-1}$.)

(c) The 360 p.p.m. of CO_2 in the atmosphere corresponds to 760×10^{12} kg C. Use this fact to convert the mean increase in CO_2 per year (in p.p.m. $CO_2\,y^{-1}$) from part (b) into a rate of increase in the *total mass of carbon* in the atmosphere (in 10^{12} kg C y^{-1}).

(d) Compare your answer to part (c) with the estimated rate of release of carbon into the atmosphere by humans through fossil-fuel burning and deforestation, which is 7×10^{12} kg C y^{-1}. Is the latter value larger, smaller, or about the same as the atmospheric increase?

Activity 8.5 An element on the move

(*The estimated time for this activity is 60 minutes.*)

'An element on the move' is the first of many DVD-multimedia activities in the course. These activities combine a variety of media in interactive learning packages that require a high level of participation on your part. They are probably very different from other learning materials that you have experienced, so you need to consider how to make best use of them.

Learning with DVD-multimedia

You should use paper and pencil to jot down key points, make brief summaries, write down answers to questions, etc. You may also want to make a note of things that you don't understand, and things that you want to discuss with other students or with your tutor. Alternatively, you can make use of the *Windows* Notepad accessory. Of course, there will be some things that you want to look up in the associated book straightaway, so it's worth keeping it handy. However, remember that the Glossary is always available (once you have run the installer) if you want to look up a term that you are unsure of.

The different activities, and the different parts of each activity, will present a variety of menus, buttons, windows, tools and so on for you to interact with, and we recommend that you spend a little time at the outset familiarizing yourself with what these do. Remember that you can't do any damage to your computer or the software by exploring like this; the worst that could happen is that the program 'crashes', so that you have to restart it from the Guide.

All the DVD-multimedia activities begin with an 'Introduction', which sets the scene for what follows, and will usually indicate the aims of the activity. The aims may also be presented under one of the menus or in the Study File notes: if they are not, you may want to make a note of them as they will help you to keep focused on what you should be getting out of the activity. When you have finished, it is always worth reflecting on whether you have satisfied these aims.

Working with these DVD-multimedia activities is an engaging experience; however, it is easy to forget what your primary aims are and to explore at random, making use of the freedom of choice that is offered. You will generally find that a systematic and planned approach is most efficient. For example, in this first activity you will have to visit 13 carbon reservoirs and explore 12 processes for moving between them, and you will therefore need to plan the routes you take. (In Activity 9.2, you will investigate the effect of a range of different factors on the GMST, and here again a systematic approach will pay off.)

Many of the activities encourage you to explore, but rather than simply trying things out to see what the result is, it's worth asking yourself 'What will happen if I do this?'. Trying to predict the outcome, and then checking whether your prediction is correct, is an excellent way of assessing how well you understand what is going on.

Just as with printed material or video sequences, you will not always absorb the DVD-multimedia message the first time. However, there are facilities to replay audio or video clips, or to scan rapidly through animations, and it is generally easy to retrace your steps through the activity. Don't hesitate to use this facility, especially when you think you have missed points in the instructions or want to find information to answer a question.

Finally, it is important when studying these activities to keep an eye on the time. Some of them provide a wide range of resources to explore, far more than you can cover in the allocated time, and you will need to be selective in what you look at (unless you are ahead with your studies and have plenty of time to spare!). We have indicated in the Study File notes for each DVD-multimedia activity an estimate of the time that we think you should spend on it.

Introduction to Activity 8.5

In this activity, you will build on what you have learnt about the carbon cycle in Section 8 of Block 2. There we divided the world's carbon between *seven* different reservoirs, but that is only one of many possible divisions; here we have chosen to divide the carbon between 13 reservoirs. Likewise, the processes by which carbon is transferred between reservoirs can be specified in various different ways, and here we have simplified the description of these carbon transfers into 12 processes. This means that we have grouped some of the transfers together under a common heading, and we have omitted some of the less important transfers altogether.

Your primary aim in this activity is to visit all 13 of the carbon reservoirs in this version of the cycle, and in doing so, to use at least once each of the 12 processes that are available for moving between the reservoirs. This will allow you to reinforce your current knowledge of the carbon cycle, and to investigate a wider range of reservoirs and processes than you have studied so far in the block. However, bear in mind the advice above about keeping an eye on the time If you find that the activity is taking longer than estimated, and particularly if you are having difficulty visiting all of the reservoirs or using all of the processes, then you can access the reservoirs and or processes that you have missed by clicking on the appropriate menu at the top of the window.

We have listed some of the assumptions and simplifications that went into this cycle in the Comments section, and you may wish to refer to this if there are any points that puzzle you about the reservoirs or processes

Before you start this activity, you should have studied as far as the end of Section 8 in Block 2.

This activity is on the Block 2 DVD, and to start it you need to open the DVD Multimedia Guide on your computer, and click on the 'An element on the move' button in the Block 2 folder. You should start this activity now.

Activity 9.1 Writing a brief summary of earlier sections

Summarizing the previous eight sections with one or two sentences for each is not easy. It requires you to think carefully about the central 'message' of each of the sections. Try doing this from memory first. Then look at the summaries of each section, and pick out the main one or two ideas from each.

How did your lasting impression of each section compare with the main message from each summary? If they are different, can you identify why?

Activity 9.2 Global warming and cooling

(*The estimated time for this activity is 60 minutes.*)

This second DVD-multimedia activity in Block 2 is rather different in style from the first one, Activity 8.5 'An element on the move', which was very pictorial, with lots of video clips. Activity 9.2 is based on two computer models of the Earth's climate system, and your task is to use these models to explore how the GMST changes when various factors that control climate are changed.

By way of preparation for Activity 9.2 you should have read Section 9.1.1. If you have not already done so then you should read that section now, and return to this point in these notes.

Before you start Activity 9.2 you should examine TMA 02 to see if particular results from the model are needed for the TMA. In any case, and as for earlier activities involving DVD, you should have paper and pencil handy.

'Global warming and cooling' is on the Block 2 DVD. To start this activity, you need to open the DVD Multimedia Guide on your computer, and click on the 'Global warming and cooling' button in the Block 2 folder.

Activity 9.3 The effect on the GMST of dust in space

This activity requires you to apply your knowledge of the GMST and the factors that determine it to a new situation. This is a good way of assessing your grasp of what you have learnt.

Imagine that a sheet of dust moves into the region of space between the Earth and the Sun. State and explain any effect this dust would have on the solar luminosity, the solar constant, and the GMST. You can write your answer in note form or as a piece of continuous writing of about 100 words. You should include a labelled sketch of how the GMST might change with time from the initial value to the new value.

Activity 9.4 Variations in the GMST versus changes in various factors

(*The estimated time for this activity is 20 minutes.*)

In no more than 200 words overall, summarize *in your own words* the effects on the GMST through the Earth's history of changes in the following two important factors:

- the amount of CO_2 in the atmosphere,
- the solar luminosity.

You should concentrate on the *time-scale(s)* and on the *size* of the GMST variations.

If you need further guidance on how to do a writing activity of this sort, look back to the general advice given in Activity 3.1.

When you have written your account, read it through and ask yourself.

- have I covered the areas specified (effects on GMST of CO_2 and solar luminosity, time-scales and sizes of GMST variations)?
- is the summary organized in a logical order?

Activity 9.5 Models in science

In Section 6 you met the particle model of solids, liquids and gases. In Section 9 you met two further types of model, namely mathematical models and scale models.

(a) Describe, in note form or as a 50–100 word summary, the main general characteristics of mathematical and scale models.

(b) Given that a model is a simplified representation of the real world, which aids understanding by focusing on some particular aspect of reality, state at least one simplification made in (i) a climate model and (ii) a globe a scale model of the Earth.

Activity 10.1 The effect of human activity on atmospheric CO_2

On the basis of your study of Section 8, which two human activities are thought to have caused an increase in the amount of CO_2 in the atmosphere? In each case explain how this has happened. Your summary should be 150–200 words in total

Activity 10.2 Summarizing climate models

This activity and Activity 10.3 are intended to emphasize the importance of planning what you write. On both occasions we ask only for an answer in note form, but you should think carefully about what the question is asking and then structure your answer accordingly. In this case this means putting your notes into a sensible order. If you would like to turn your notes into a continuous piece of writing, then we have included an answer written in this form for comparison.

Summarize, in note form, the main achievements and shortcomings of climate models. (Clearly you need to find both achievements and shortcomings, and you will probably want to keep these separate in your answer.)

Activity 10.3 Human consequences of a rise in the GMST

This activity is intended to give you practice at planning a longer piece of writing at the same time as reflecting on the different styles of writing that will be developed through *Discovering Science*

(a) Suppose that you have read an article in your local newspaper in which the author argues that, even if we accept that the Earth's temperature will rise over the next century as many scientists predict, this could only be regarded as 'a good thing' — especially given the UK's mediocre climate. You feel strongly that such a naive argument shouldn't go unchallenged.

You plan to write a letter to the newspaper editor explaining some of the potential consequences for human society of the likely rise in GMST. Using material from Block 2, especially Section 10.3, and the skills that you have learnt about extracting information from text, draw up a list of the points that you would make in this letter. Then put your points into a logical order.

(b) If you were to use your ordered list of points from part (a) to write a section of a factual book about global warming for people who are hoping to study S103 next year, what would be the similarities and differences between this and your letter to the editor? (You should find it helpful to look at *SGSG* Chapter 9 Section 2.)

Activity 11.1 Reviewing your study of Block 2

(*You should spend at least 15 minutes on this activity*)

This block covers a wide range of different science concepts, drawn from biology, chemistry, Earth science and physics, and many of these concepts will be new to you. Also, it introduces a large number of new scientific terms In this activity we would like you to reflect on how you have coped with all of the new science that you have studied in Block 2.

(a) First, think about the new terms introduced in the block. Scan through the book index, and note down any bold terms for which you are not sure of the meaning. Now think about occasions while you were studying the block when you came across terms that you were unsure of.

- What strategies did you adopt to clarify the meanings of the terms?
- Do you have any strategies for helping you to remember new scientific terms?

Now read through the list of objectives for Block 2 in this Study File, and indicate with a pencil in the margin whether you think that you can meet each objective.

Then think about those terms and objectives that you have identified.

- Are some of them related to each other?
- Do many of them relate to a particular section?
- Can you identify why it is that you have had difficulty with these items?

Possibly it is because they were completely new to you, whereas you had met other topics before; or maybe they involved a lot of new scientific terms, or perhaps the more mathematical concepts gave you trouble. Try to note down a few areas where you think that you are coping well and note why, and a few areas where you are doing less well, or are struggling, and what strategies you are using to cope with these areas.

(b) Now think about how your learning has changed since you began Block 1.

- How are you using questions and activities?
- Are you making summaries?
- How are you highlighting and annotating the book as you study?

In the light of your experience, what advice would you give yourself about how to learn the science in the next block?

(c) Are there other ways that you have found for helping you to learn the science in the course? Make a list of any additional ways of studying that have helped you to learn the science.

(d) Finally, you may wish to spend some time on the bold terms and objectives that you identified in part (a). In particular, you could look up in the Glossary the definitions of terms that you are unsure of, and you could have another try at questions and activities related to the objectives that you were unsure of.

You should complete your study of Block 2 by trying the rest of the questions on the Block 2 DVD

Acknowledgements

Grateful acknowledgement is made to the following sources for permission to reproduce material in this study file:

Figures 2.1.1: 'Around Britain yesterday', *The Times*, 13 September 1997, © Crown Copyright. Reproduced with the permission of the Controller of Her Majesty's Stationery Office; *Figure 2.1.3*: Woodley, K. E. 1980, *Hydrological Memorandum No. 44: Maps of average monthly rainfall over the British Isles for 1941–70*, National Meteorological Library and Archive, © Crown Copyright. Reproduced with the permission of the Controller of Her Majesty's Stationery Office.

Comments on activities

These comments should be read after *you have attempted the activity for yourself For most activities there is no one 'correct answer', so we either provide a 'sample answer' to the activity (sometimes produced by a student), or we provide guidance on how you should have tackled the activity and what you might have written in your Study File. We also provide advice about how you might improve particular skills, and this should help you when you tackle similar activities in later blocks or in assignments*

Activity 1.1

(a) You now have a plan to help you in your study of Block 2, and you will be encouraged to amend this, if necessary, when you have studied about half of the block

(b) At this early stage of the course, you should experiment with a range of study methods and techniques to find out what works best for you. We will ask you to think about this in a couple of activities while studying this block

Activity 2.1

Task 1

Here are some of the issues that you might have considered when thinking about these questions.

What type of collecting vessel will you use? To collect the precipitation you need a *straight-sided* container that is sufficiently deep that it does not overflow between measurements. If the vessel were cone-shaped, as shown in Figure 2.1.4, then you would collect water over an area defined by the mouth of the cone, but you would measure the depth of a pool of water which covered a smaller area at the base of the container. So the depth of the water in the container would be greater than the depth that would be measured in a straight-sided container of the size of the mouth of the cone

Figure 2.1.4 The measured depth in a cone-shaped collecting vessel would be greater than the true precipitation

The container that collects the water will be exposed to the air at all times. Did you consider what would happen to the water in the container when the weather is dry? The water will evaporate, just as a puddle of water evaporates, and clearly this may lead to measurements that are lower than the actual amount of precipitation. So you need to take precautions to minimize evaporation from the rain gauge. One possibility is to fit a funnel in the top of the rain gauge. This arrangement is shown in Figure 2.1.5.

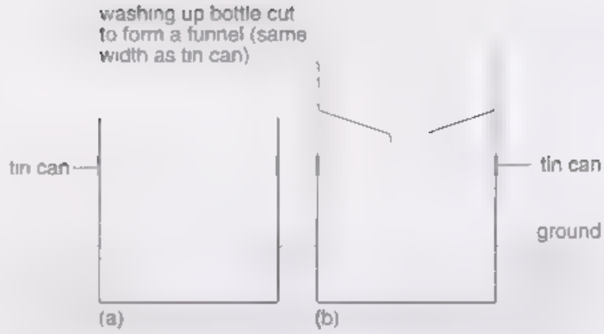


Figure 2.1.5 Two examples of home-made rain gauges: (a) without a funnel, (b) with a funnel

Where will you site the gauge? A rain gauge needs to be placed in an open situation so that it is neither sheltered from the rain by overhanging objects, nor liable to catch drops spilling off objects. Because it will be left out for three or four weeks, it needs to be fairly stable, so that it is not easily blown over by the wind or knocked over by animals, and it needs to be located in a place where people won't trip over it.

How will you measure the amount of precipitation? You will need a ruler or tape measure to measure the depth of the water. You could use a dipstick, as shown in Figure 2.1.6 If you use a ruler, be sure that you allow for any unmarked length at the end when you record your measurements. You should aim to measure the depths to the nearest millimetre, or better, if you can!

How often will you record the data? Because you will be calculating the mean daily precipitation over several weeks, you could simply measure the depth of water at the end of the period and divide by the number of days However, it is more instructive if you record the amount of precipitation at regular intervals during this period. If possible, for the first week you should record the amount of precipitation daily, i.e. over seven 24-hour periods. The best way to do this is to measure the depth of the water at a particular time each day, to within a few minutes. For the second and third weeks (and the fourth week, if you have time before the start of Block 3), just measure the water level at the end of each week, again at the same time

In the first week, do you need to empty the rain gauge each day? You could do so, but you don't have to, providing the vessel is in no danger of overflowing. You can determine the depth of water that has fallen in the previous 24 hours by subtracting the previous day's depth from the current depth. We suggest you do this, and empty the rain gauge only once a week: you will see why later.

What problems might you have in measuring the precipitation? If you are measuring in February, one problem that you might have thought about is snow and ice. If there is snow or ice in your rain gauge when you want to make a measurement, then you will have to bring the gauge inside your house and allow the snow to thaw. If you are measuring in October, then one problem you may encounter is fallen leaves covering the gauge. These prevent water from collecting and may also hinder your ability to accurately measure how much water had collected

Now return to Task 2 in the notes on this activity

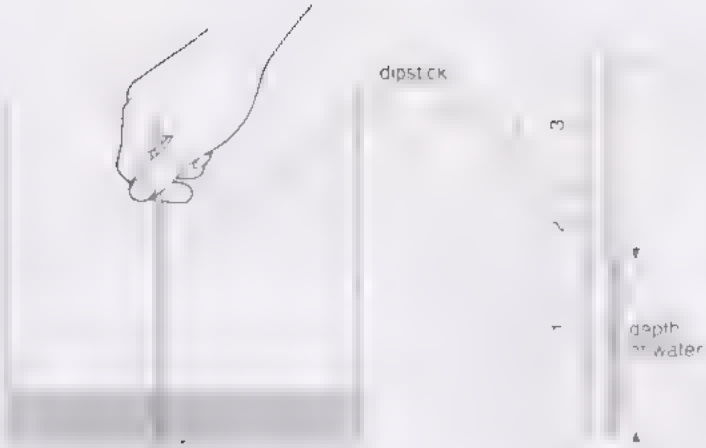


Figure 2.1.6 Using a dipstick to measure the depth of water in a rain gauge

Table 2.1.3 Precipitation measured in Milton Keynes in the period 15.2.97–21.2.97

Date	15.2.97	16.2.97	17.2.97	18.2.97	19.2.97	20.2.97	21.2.97
Time of recording	08.01	07.58	08.02	08.01	08.00	08.03	07.59
Depth/mm	6	8	12	12	15	17	20
Precipitation in previous 24 h/mm	6	2	4	0	3	2	3

Task 4

Table 2.1.3 shows some typical precipitation data obtained with a home-made rain gauge in Milton Keynes during a week in February 1997. The depth of the water was measured each day, and the depth of water collected in the previous 24 hours was calculated by subtracting the previous day's depth from the current day's depth.

The mean daily precipitation is calculated by adding together the precipitation values for each day, and dividing the total by the number of days

$$\frac{(6+2+4+0+3+2+3)\,\text{mm}}{7} = \frac{20\,\text{mm}}{7} = 2.857\,\text{mm}$$

$$= 2.9\,\text{mm (to 2 sig figs)}$$

Alternatively we can use the total precipitation for the week, the 20 mm measured on 7.2.97, and divide this by seven. This is how you should calculate the mean in subsequent weeks.

Note that we have expressed the mean to two significant figures, because the total weekly precipitation was expressed to two significant figures. The number 7 that we divide by in order to get the mean daily precipitation is an exact whole number — there is no uncertainty in the number of days in a week — so this does not affect the number of significant figures.

As discussed in the notes, if you think that the uncertainty in the value of the weekly precipitation that you measured was ± 0.5 mm (i.e. you measured the water depth to the nearest mm), then the uncertainty in the mean daily precipitation would be about ± 0.1 mm, so we would quote the result as 2.9 mm ± 0.1 mm.

Task 6

To obtain the mean daily precipitation for each week, you must divide the total precipitation accumulated over the week by seven (see Task 4). This gives you values of the mean daily precipitation for each of the three or four weeks

To obtain the overall mean daily precipitation for the period, you need to add together the values of the mean daily precipitation for each week and divide the total by the number of weeks.

You could have left the rain gauge for the complete period, and then divided the total depth of water collected by the total number of days. However, that is risky; if the water were to spill just before you measured its depth, you would lose all your data

Task 7

You probably observed that the depth of water in the open-topped rain gauge (Gauge 1) was less than that in the rain gauge with a funnel (Gauge 2), and this can be accounted for by the greater evaporation from Gauge 1. This shows the importance of designing apparatus so that possible sources of errors in measurements, such as evaporation in this case, are minimized

Task 8

One student in Birmingham, who performed the experiment in February, measured a mean daily precipitation of 2.9 mm over a three-week period. This is equivalent to a mean monthly precipitation of 28 × 2.9 mm = 81 mm. Figure 2.1.3 shows that the 30-year mean precipitation for February in Birmingham is 50–75 mm, rather less than this student measured. Newspaper reports indicated that precipitation in February in the Midlands had been greater than normal.

Task 9

Here is a conclusion from one student.

> I measured the precipitation at Birmingham from 4 February to 24 February, and the mean daily precipitation was 2.9 mm ± 0.1 mm, or 81 mm for a 28-day month. Comparison of this result with published values averaged over 30 years suggests that this year February has been a wetter month than normal in Birmingham. One of the problems of measuring precipitation is evaporation, and I found that this was reduced by the use of a funnel on top of the rain gauge.

The first sentence reports the outcome of the experiment, that is, the mean daily precipitation. It also specifies where and when it was recorded. The second sentence compares it with the mean daily precipitation in February. The third sentence reports that the use of a funnel reduced evaporation.

Task 10 Reflection on the practical work

(a) Answering the questions at the start of the practical work probably helped you to think about how to design the apparatus, and to decide what measurements to make, and may even have led you to think of a few more questions (and answers) of your own. Asking and answering questions is a good way to focus your attention on what you need to do, whether it is planning an experiment, solving a problem, or deciding what you need to learn. When the questions are not presented to you in the course material, then you should try to develop the habit of devising your own questions to help you with the activity that you are tackling.

(b) The order in which we laid out the practical work notes is typical of that used by scientists when writing up experiments — a task that you will be asked to do later in the course.

We first gave a general background to what we wanted you to investigate. (Introduction)

Then we described how to set about the experiment. (Practical procedure)

You recorded the measurements that you made (Results)

You worked with the data, putting it into a form that gave you the information that you wanted. (Analysis of results)

You thought over what you had done — and this might include any criticisms of what you did, how you could improve your own experiment, how your results compared with other people's, what you've learned and what you still need to investigate. (Review)

Finally, you summed up the outcome of the experiment. (Conclusion)

Note that by doing Activity 2.1 you should have learnt more than how much rain fell in February: you have learnt something about how to do scientific practical work. If you want to read more generally about practical work in science, have a look at parts of Chapter 8 of *SGSG*, particularly the key points in Section 2 about observing, and the part of Section 4.1 entitled 'Why experiment when you already know the results you're supposed to get?'

Activity 3.1

The following summary addresses the points mentioned in the notes for this activity and it contains the key elements in a logical order. But within this structure, the example picked to illustrate the Grande Pile results, and of course the exact wording used, are likely to be different from those in your summary. Compare your summary carefully with the one below and identify any differences

> A pollen diagram displays the proportions (or percentages) of each type of pollen in a series of samples collected from a range of depths in a sediment or peat core. The vertical axis gives the depth of the sample, increasing downwards, so the age of the samples decreases upwards on the diagram, allowing the history of vegetation change to be displayed Any change in the proportions of different plants, seen as a change in the proportion of different pollens, signifies some sort of climatic change because a region's climate influences the types of plant growing there. Thus, a knowledge of the plant population can be used to infer the prevalent climate conditions, including temperature. For example, in the Grande Pile core from France, reductions in the proportion of tree pollen in particular periods are interpreted to signify a reduction in the long term mean temperature. (*145 words*)

Once you had written your definition of a pollen diagram, did you look in the Glossary to check the definition given there? Remember that this is a handy source of reference, though you should always try to express a definition in your own words rather than simply copying out a definition from the Glossary.

Summarizing in this way can help you to develop your writing skills. (Further advice on writing is given in *SGSG* Chapter 9, Section 5.) Summarizing is also a good way of reinforcing your understanding of the text. You will be able to practise producing written summaries in Activities 9.4 and 10.1, and there are also several activities in this block that ask for summaries, but suggest that the summary can be written in note form. If you feel that you need more practice at writing, you could try translating your notes for these activities into a continuous piece of prose.

Activity 4.1

(a) When the slot is narrowed the leak rate is smaller. Therefore, the water level rises, and this means that the leak rate increases until it again equals the rate of inflow from the tap. The new steady-state level has then been reached, with the water at a higher level, as shown by the diagrams of the tank in Figure 4.1.1a. The sketch graph shows how the water level changes after the slot is narrowed

(b) When the slot is widened the leak rate is larger. Therefore, the water level falls, and with it the leak rate, until the new steady state is reached with the water at a lower level, as shown in Figure 4.1.1b.

You will find it instructive to compare the shapes of the graphs in Figure 4.1.1 with those in Figures 4.3 and 4.4 in Block 2, which also show the transition from one steady state to another. In each case the water level (or GMST) changes most rapidly at first, and changes more slowly as the new steady state is approached

The leaky tank analogy was thought up to help you to visualize the more abstract changes in the GMST Thinking of analogies like this is a useful skill to develop. If something in the course text puzzles you, try thinking of an analogy for yourself

Activity 4.2

Here is a sample summary in note form.

> Rate of water flow into tank represents rate of energy gain by Earth's surface.
>
> Leak rate represents rate of energy loss.
>
> Level of water represents GMST.
>
> When flow rate into tank equals leak rate, water level is steady.
>
> So when rate of energy gain equals rate of energy loss, GMST is constant
>
> If inflow rate or leak rate is changed, then water level changes immediately until the two are again equal.
>
> So GMST changes immediately following a change in rate of energy gain or loss.

If you wrote this as a piece of prose it would look something like this.

> The rate at which water flows into the leaky tank represents the rate of energy gain by the Earth's surface, and the leak rate represents the rate of energy loss The level of water in the leaky tank represents the GMST and this level is steady when the rate of inflow equals the leak rate. This demonstrates that the GMST does not change if the rate of energy gain by the Earth's surface equals the rate of energy loss.
>
> If either the leak rate or the inflow rate is changed, then the water level immediately starts to change until the two rates are again equal. This demonstrates that the GMST changes immediately following a change in the rate of energy gain or loss. *(123 words)*

In this activity you have summarized a section of text. Doing this should have helped you to understand the text better, and of course you will now have notes that will help with assignments. It is also useful to have a summary of the salient points when it comes to revising for an examination.

You may already be summarizing all that you read, as was recommended in Block 1. If you are doing this, it might be useful to check your summaries against the section summaries in the block. They will not, of course, be the same, but they should include the same key points

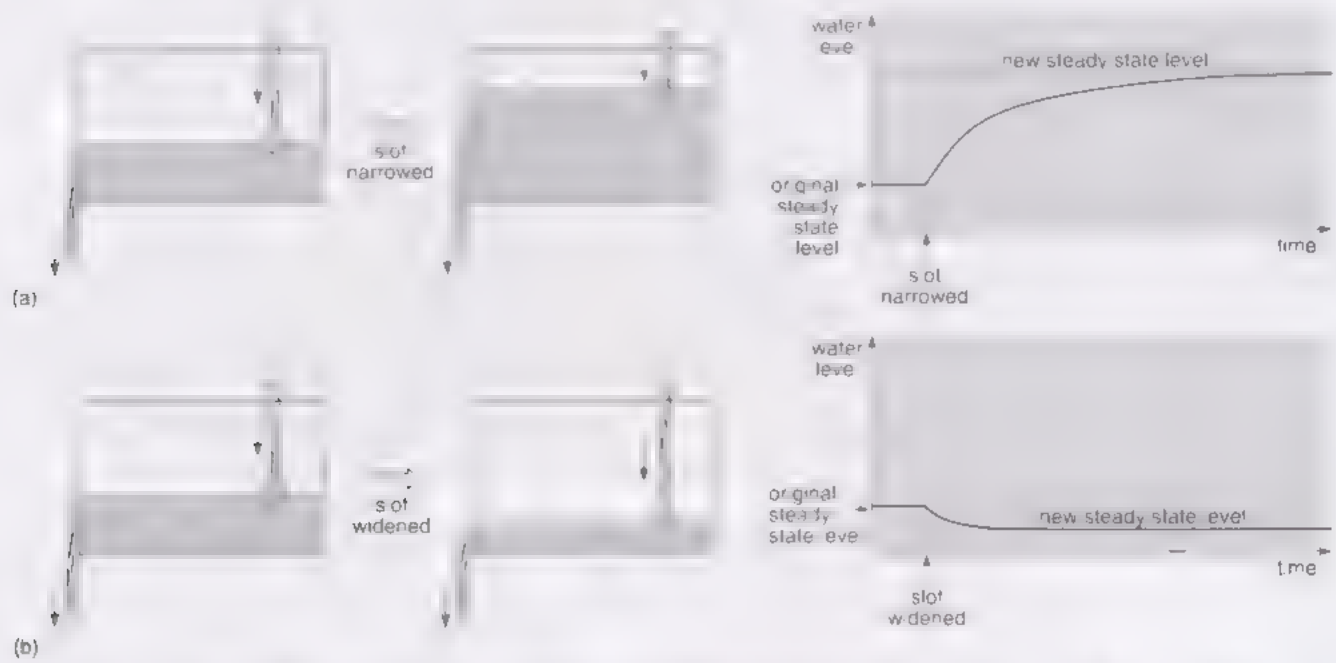


Figure 4.1.1 How the water level in a leaky tank changes if the input from the tap remains constant but the slot in the tank is (a) narrowed and (b) widened

Table 5.1.2 Completed table of results from the radiant heating experiment.

Clock time /minutes:seconds	Uncoated plate temperature/°C	Black-coated plate temperature/°C	Elapsed time since lamp switched on /minutes:seconds	Uncoated plate temperature increase/°C	Black-coated plate temperature increase/°C
26:00	18.5	18.5	0:00	0.0	0.0
27:00	19.0	20.0	1:00	0.5	1.5
28:00	20.0	22.0	2:00	1.5	3.5
29:00	20.5	24.5	3:00	2.0	6.0
30:00	21.5	26.5	4:00	3.0	8.0
31:00	22.5	28.0	5:00	4.0	9.5
32:00	23.0	30.0	6:00	4.5	11.5
33:00	24.0	31.0	7:00	5.5	12.5
34:00	24.5	32.0	8:00	6.0	13.5
35:00	25.0	33.0	9:00	6.5	14.5
36:00	25.5	33.5	10:00	7.0	15.0
37:00	26.0	34.0	11:00	7.5	15.5
38:00	26.0	34.5	12:00	7.5	16.0
39:00	26.5	35.0	13:00	8.0	16.5
40:00	26.5	35.0	14:00	8.0	16.5
41:00	27.0	35.5	15:00	8.5	17.0
42:00	27.0	36.0	16:00	8.5	17.5
43:00	27.0	36.0	17:00	8.5	17.5
44:00	27.5	36.0	18:00	9.0	17.5
45:00	27.5	36.0	19:00	9.0	17.5
46:00	27.5	36.0	20:00	9.0	17.5

Activity 5.1

Tasks 1 and 2

Table 5.1.2 is a completed version of Table 5.1.1.

Task 3

Figure 5.1.6 shows a graph of the data in columns 4–6 of Table 5.1.2. You can see the general trends from the plotted points, but we can do better than this by sketching a curve that follows the general shape of the points. This is illustrated in Figure 5.1.7. The justification for using a smooth curve is that we expect the temperature to increase smoothly, and so a smooth curve that passes as close as possible to the points is the best representation of the temperature change. The plotted points do not all lie on the smooth curve because each measurement has an uncertainty of about ±0.5 °C, and so there is an equivalent uncertainty about where the point corresponding to the true temperature would lie on the graph.

Task 4

(a) The plate temperatures rose because the bulb emitted radiant energy, some of which the plates absorbed (see Block 2 Section 5.1.1)

(b) The black-coated plate reached a higher temperature than the uncoated plate. This was because it absorbed a greater fraction of the radiation that it intercepted.

(c) The tendency towards unchanging values of temperature with time is evidence that a steady state was being approached.

A new steady state was approached because as the plate temperature rose, the rate of energy loss increased. In the new steady state, the rate of energy gain from the lamp, plus the other sources that were present before the lamp was switched on, equalled the rate of energy loss (see Block 2 Section 4.1.1).

(d) Irregular temperature variations, or a slight fall, can have several causes, singly, or in any combination: variable draughts; fluctuations in mains voltage to the light bulb, changes in room temperature.

(e) With a higher wattage bulb the new steady-state temperatures would be higher. This is because the rate of energy gain from the lamp would increase, so the plates would have to reach a higher temperature before the rate of energy loss equalled the rate of energy gain. (Block 2, Section 4.1.1).

Task 5

One possible conclusion is as follows:

Conclusion

This experiment showed that when an object initially in a steady state is exposed to an extra source of radiant energy, it absorbs some of this energy, and as a consequence its temperature rises until it reaches a new steady state. It also showed that objects differ in the degree to which they absorb radiant energy. The black plate absorbed more energy than the bare plate, and therefore reached a higher temperature.

Now look back to the predictions that you made at the start of this activity: did you correctly predict the results of this experiment? If you did, then you have probably grasped the important ideas about absorption, reflection and steady states. You should try to develop the habit of asking yourself: 'Is my result reasonable?' If your results are consistent with your predictions, then you can have some confidence in your understanding of the situation and in the result obtained. If they are not, you need to check back to see why not: perhaps you misunderstood a

key concept (absorption or reflection, for example) or you did not apply it correctly in this case, or you made a mistake in calculations. When a result is not what you expect, it should set an alarm bell ringing. Many mistakes are found in this way, but also many great scientists have made splendid discoveries by identifying why their results were different from what they expected.

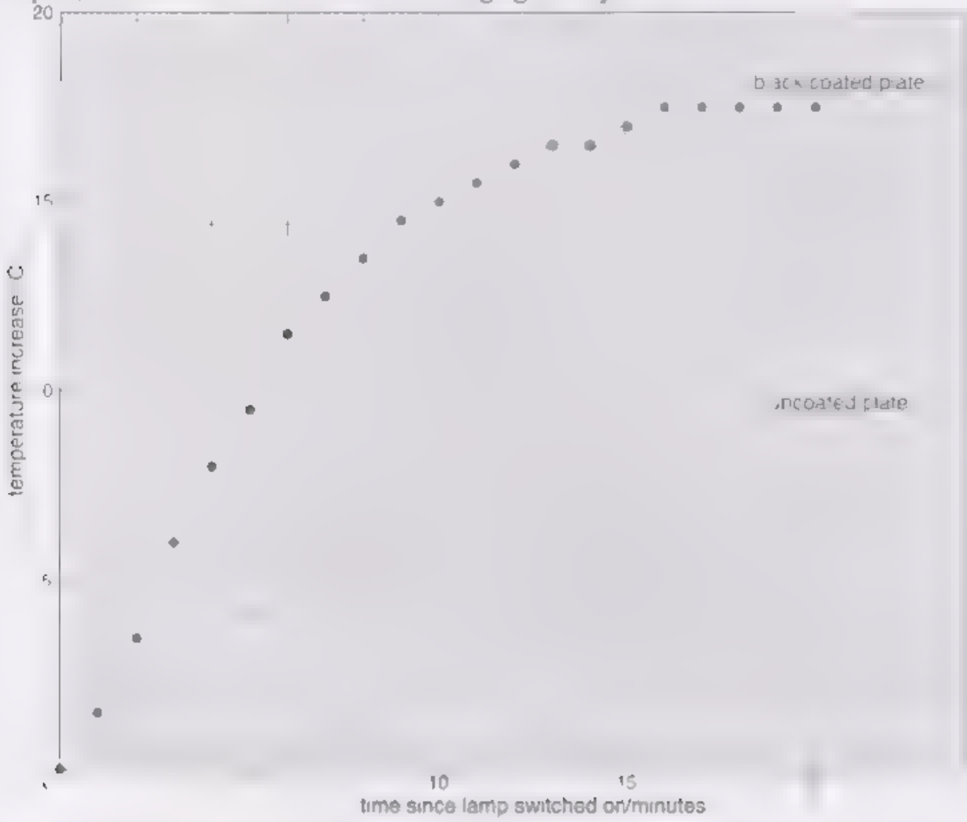


Figure 5.1.6 The data in Table 5.1.2 plotted on Figure 5.1.5.

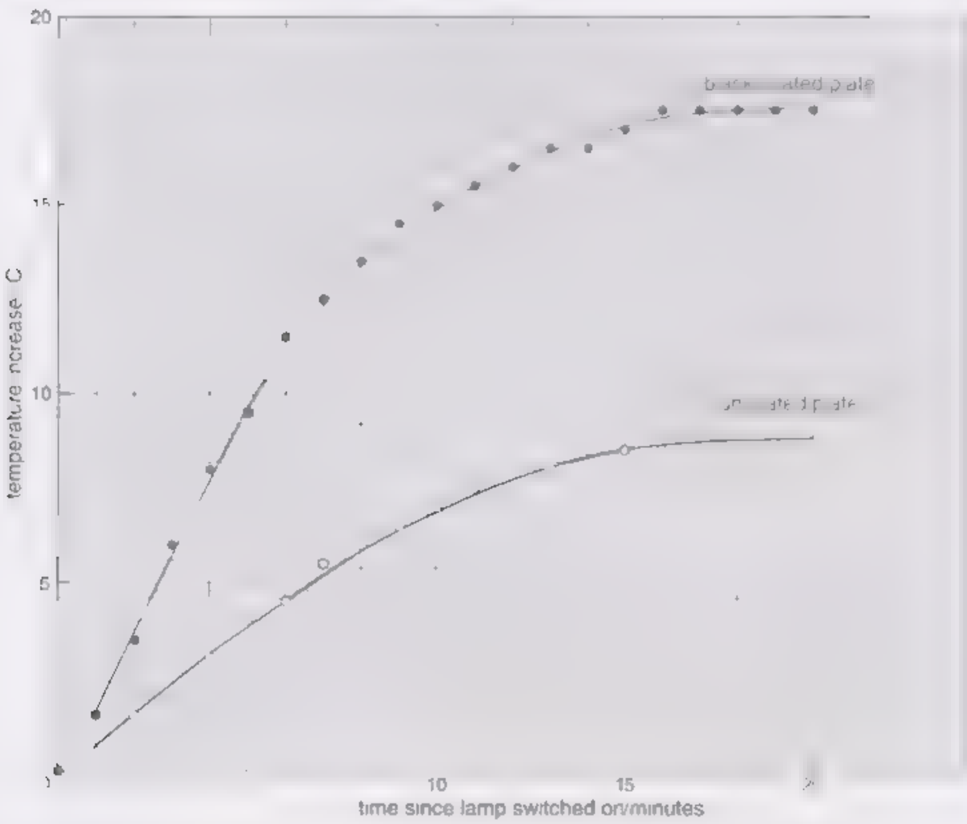


Figure 5.1.7 The same data as plotted in Figure 5.1.6, with a smooth curve added to show the trend of the measurements. The curve representing the data does not have to pass through all of the data points.

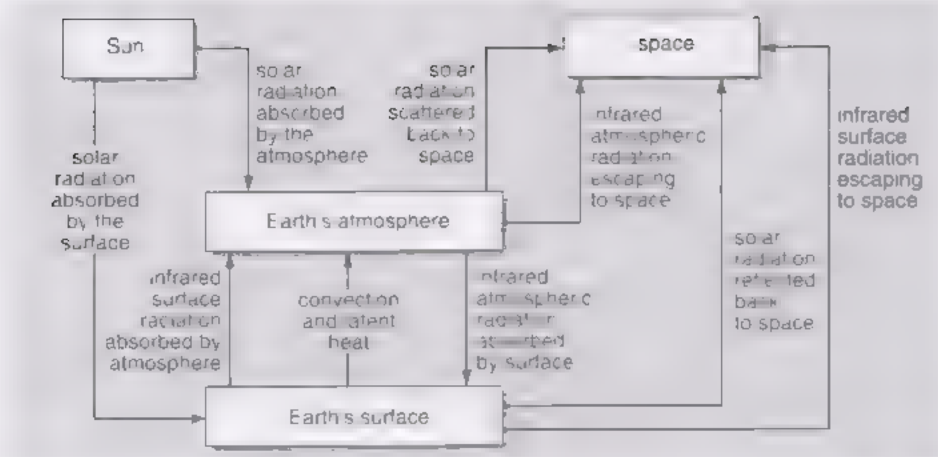


Figure 5.2.2 Completed flow diagram for Activity 5.2

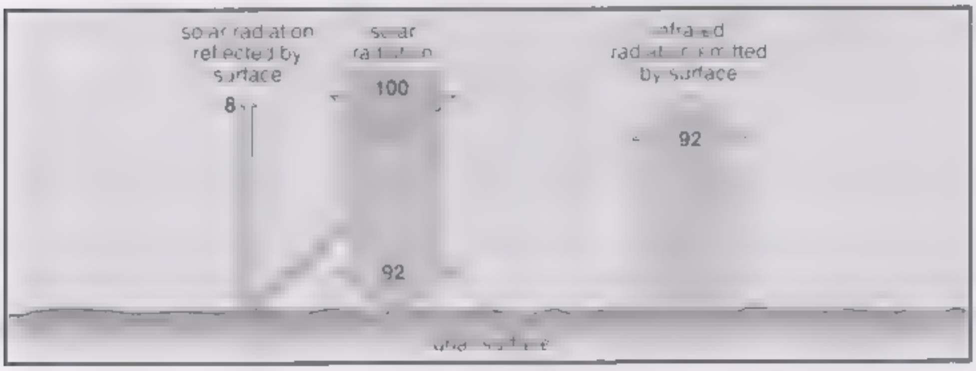


Figure 5.3.1 An energy balance diagram for the Moon

Activity 5.2

Figure 5.2.2 shows a completed flow diagram. It contains all of the energy transfers shown in Figure 5.14, but it is laid out in a different way and the reflection and scattering of solar radiation are shown separately. Also it doesn't show the numerical information. Your labels may be slightly different from ours but they should convey the same meaning. This kind of flow diagram can act as a useful at-a-glance summary, as can the version in Figure 5.14. The use of flow diagrams is further discussed in *SGSG* Chapter 3, Section 3.1.

Activity 5.3

(a) Our energy balance diagram is shown in Figure 5.3.1. Yours may not be the same style, but it should show the same features.

(b) The 100 units represent fewer watts in Figure 5.3.1 than in Figure 5.14 because, even though the average distance from the Moon to the Sun is the same as that from the Earth to the Sun, the Moon is considerably smaller than the Earth — only about 7% of the surface area — so it will intercept much less solar radiation

(c) The downward arrow at the top represents the rate at which solar energy is *intercepted* by the Moon: 100 units. The arrow on the left represents the rate at which solar energy is *reflected* by the Moon: 8 units (8%). The arrow that penetrates the lunar surface represents the rate at which solar energy is *absorbed* by the lunar surface: this must be 100 − 8 = 92 units. The remaining arrow represents the rate at which energy is *emitted* by the Moon at (longwave) infrared wavelengths. With the mean surface temperature of the Moon not changing, the rate at which energy is emitted from the surface must equal the rate at which it is absorbed by the surface: in a steady state, the rate of gain must equal the rate of loss. Therefore, 92 units are emitted from the surface.

Note that the radiation emitted from the Moon's surface is in the (longwave) infrared region of the electromagnetic spectrum whereas the solar radiation that is absorbed has its peak in the visible region of the spectrum. This is very similar to the situation for the Earth, which is illustrated in Figure 5.11 of Block 2, and is a consequence of the difference in temperature between the Sun and the Moon. The energy balance diagram for the Earth (Figure 5.14) shows that the power of the intercepted solar radiation (100 units) is less than the power of the radiation emitted from the Earth's surface (114 units) because of absorption and emission from the atmosphere. This means that the curve on the left in Figure 5.11 corresponds to a lower power than the one on the right. In the case of the Moon, the power of the intercepted solar radiation (100 units) is greater than the power of the radiation emitted from the Moon's surface (92 units), so the equivalent version of Figure 5.11 would show the power of the intercepted solar radiation peak on the left as greater than the power of the emitted radiation peak on the right.

(d) (i) If the lunar surface became more highly reflecting to solar radiation, then the rate of energy gain would initially be less than the rate of loss. The surface would thus cool. As the surface temperature fell the amount of infrared radiation emitted would fall, until the new steady-state temperature were reached; then the rate of energy loss would again equal the (reduced) rate of gain.

(ii) If the Moon acquired an atmosphere with the properties described then there would be a substantial greenhouse effect — the lunar mean surface temperature would increase.

In this activity you have applied concepts that have been introduced in the block to a new situation, and this is an excellent way of reinforcing your understanding, and also of identifying any gaps in your understanding. This is one of the roles for the questions and activities in the course and for the DVD and assignment questions.

Activity 5.4

(a) If you think you cannot find sufficient time to complete Block 2, including the assignments, within the allotted four weeks, ask for advice from your tutor-counsellor. Don't hesitate to make this contact; your tutor will be able to suggest strategies for keeping up with the work.

(b) Try to build on what you do well, and don't persist with what is going badly without trying different ways of working. You will find it useful to talk to other S103 students about how they are managing their time and how they are studying the course. Almost certainly you will find that some of them have similar problems to your own, and you will be able to help each other by sharing useful tips.

(c) Here is a comment from a student about this type of activity, in which you review how well you are learning.

> Initially I was annoyed. I wanted to learn science and I thought that some of the activities weren't very helpful ... I find making notes like this difficult but it does help me to understand and remember things. I try to explain things to someone else too. I now discuss the course with my family, and I'm enjoying the course more because of this.

'Active reading' can be helpful to all students, but there are almost as many personalized versions of the process as there are OU students. Some people make copious notes, some draw diagrams, others (like the student quoted above) discuss the course with others. Don't feel that you have to stick with one method all of the time. We shall continue to suggest different ways of studying, and we would encourage you to use the ways that work best *for you*.

Activity 6.1

You shouldn't be concerned if you were unable to think of many points to write down. We shall return to your list at the end of Section 6.5, and you will then be able to see how your knowledge of the air has developed.

Activity 6.2

Your completed version of Table 6.2.1 should provide a good summary of the evidence from the DVD-video that the air has substance, and you will make use of this information in Activity 6.5.

This type of exercise, which involved the critical evaluation of evidence, is important in most areas of scientific endeavour. Scientists need to keep asking questions like 'what is it that I'm really observing or measuring?', and 'does this provide evidence for ...?'

Activity 6.3

The layout, wording and amount of detail on your diagram are probably different from the examples in Figure 6.3.1 (*overleaf*). However, the important thing is to check whether you have identified the main subtopics and the links between them.

Activity 6.4

The answer to the question at the end of the DVD-video is as follows.

In a gas, the particles are moving around well separated from each other, occasionally bumping into one another. However, there is little attraction between the particles — so the gas has no fixed volume and can flow. As the gas cools, the particles slow down. Eventually, the gas reaches a temperature where the gas condenses, that is, it is converted into a liquid. This transition involves the particles moving from a state where the particles are spread out to one where the particles are close together with a strong attraction between the particles. The particles still move around each other, so that although a liquid has a fixed volume it will flow.

Further cooling of the liquid means that the particles move around ever more slowly. When the liquid is cooled to the freezing temperature it undergoes a transition to a solid. In the solid state the particles are close to one another but occupy fixed positions. This is why a solid has a fixed volume and a fixed shape — it will not flow. However, the particles can still move to some extent; they can vibrate, although the vigour of the vibration decreases as the temperature is lowered further.

Activity 6.5

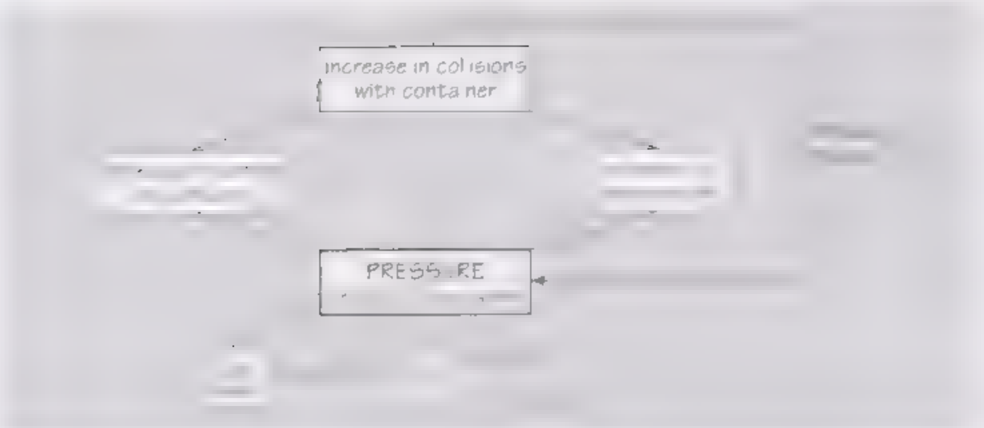
Demonstrations 1, 3, 4, 6 and 7 showed that air has substance.

Demonstration 1 This showed objects being buffeted by the wind. Wind involves movement of the air and thus a net movement of particles. If the movement of air is large enough, as the particles collide with an object they cause the object to move. The DVD-video started with someone parachuting. Particles in the air were caught in the parachute, holding it open. The descent was slowed because particles of air below the parachute canopy resisted its descent.

Demonstration 3 Animals and plants need to breathe air to live. Some of the particles in the air seem to be necessary for life. When we breathe in, we take particles into our bodies.

Demonstration 4 As the tyre was inflated, more particles were pumped into it. The greater number of particles exert a greater force on the tyre because of the greater number of collisions with the tyre wall. This internal force resists attempts to squash the tyre, which means that the tyre feels much 'harder'.

Demonstration 6 The mass of the bottle before and after pumping was different because the pump forced more particles into the bottle. Because the particles have mass, the mass of the bottle plus its contents increased.



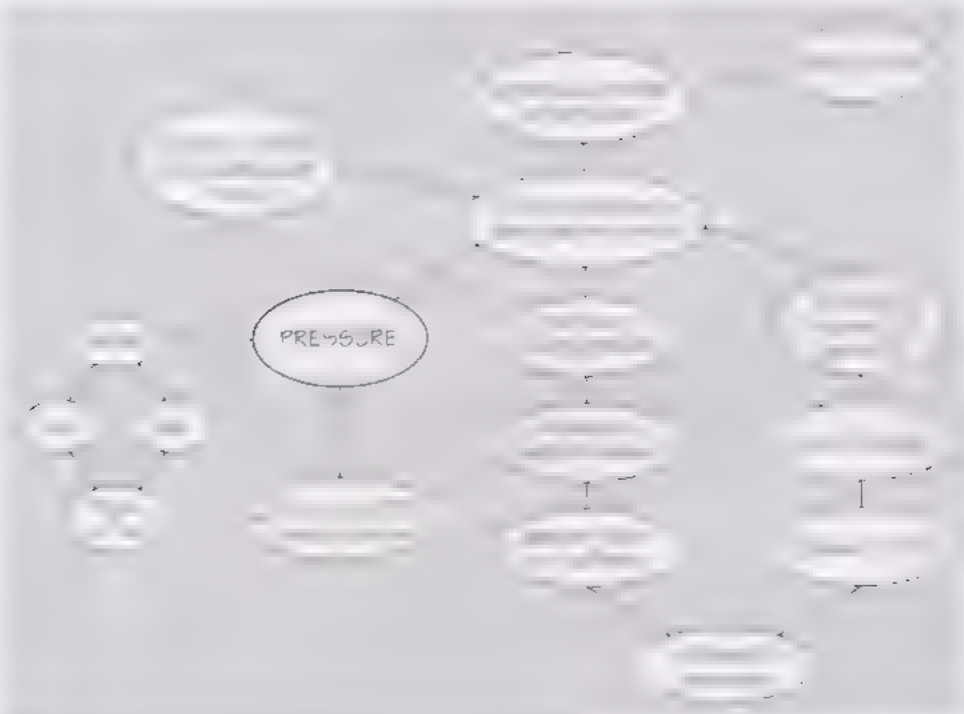


Figure 6.3 1 [illegible]

Demonstration 7 Birds fly or hover by flapping their wings, which effectively push down on the air. As the wing goes down, the particles in the air need to be displaced and it is a resistance to this displacement that keeps the bird aloft.

Did asking the questions that we suggested help you to explain these demonstrations? Thinking in terms of questions like these can often help you to get to grips with a new concept: try asking yourself 'why does this happen?', 'what would happen if ...?'

Scientists often explain their observations using a model, in this case the particle model. By using the model to explain different observations, they test out its validity, and get a better picture of its limitations. Sometimes they decide that the model cannot explain particular observations, and they modify the model or look for an alternative model. Sometimes, as here, using the model in different situations can clarify or deepen understanding of the model.

Activity 6.6

The notes you made on this DVD-video should contain the following points.

The air is a mixture of gases comprising:

Nitrogen (77.6%)

- colourless gas
- liquid nitrogen boils at −196 °C
- nitrogen gas is reluctant to react with many substances — it does not support combustion or life

Oxygen (20.9%)

- liquid oxygen is blue
- liquid oxygen boils at −183 °C
- oxygen is a reactive gas, a test for oxygen is relighting a glowing splint
- oxygen supports combustion and life
- things that burn reasonably well in air burn very vigorously in pure oxygen

Water (0.5% variable)

the water cycle ensures that water is circulated around the Earth

Carbon dioxide (0.036%)

carbon dioxide goes direct from a solid to a gas and vice versa at atmosphere pressure

under high pressure carbon dioxide does form a liquid

Argon and the noble gases (0.93%)

the noble gases are helium, argon, neon, krypton and xenon

they are called noble because they do not react with other substances

Please note that if you come into contact with liquefied gases, *you should not try to emulate the demonstrations that you saw in this DVD-video.* The presenter of the demonstrations is very experienced with handling liquefied gases, and the reason he didn't get a frost burn from contact with the liquefied gas is that heat from the skin vaporized the liquid and formed an insulating layer of gas. However, this only protects from frost burns for a very short time. It is easy to get very severe burns from mishandling liquefied gases, and protective clothing is normally worn when working with them.

Activity 6.7

(a) Here's the list produced by a member of the course team after reading Section 6. You may have omitted a few of these points, and you may have included some extra details — there is no single 'best' list!

Properties of the atmosphere

has mass

is essential for life

is a gas, and can be understood in terms of a particle model

collisions of air particles are responsible for air pressure

air pressure is 1 bar, 15 p.s.i. at ground level

pressure and number of particles per m^3 decrease with altitude

density decreases as temperature increases — leads to convection

winds are caused by different heating of air in different regions

reduces solar radiation reaching surface

absorbs infrared radiation emitted by surface

emits infrared radiation

allows loss of energy from surface by convection and latent heat

Composition of the atmosphere

nitrogen 78%, oxygen 21%, argon 1%, water 0.5%, carbon dioxide 0.04%

nitrogen and oxygen are elements, two atoms in each molecule

argon occurs as single atoms

water and carbon dioxide are chemical compounds, with each molecule containing three atoms

oxygen is very reactive, essential for animal life and burning fuels

nitrogen and argon are very unreactive

nitrogen, oxygen and argon are not greenhouse gases

water and carbon dioxide are greenhouse gases because their molecules contain more than two atoms — increasing the amounts of these gases in the atmosphere will increase the GMST

(b) The comparison of your current list with the one you produced in Activity 6.1 should show how much your knowledge of the topic has increased, and should also demonstrate the importance of the particle model in providing a framework to explain and develop our ideas.

(c) Some at least of your questions should have been answered, but there is a lot to know about the air, and we have been able to focus on only a few key aspects. If you have outstanding questions, you may like to discuss them with other students or your tutor.

Activity 7.1

(a) Before the bowl of water is added, the rate at which water enters the tank matches the rate at which it is pumped out, so the water level is in a steady state. When the bowl of water is added the level of water in the tank increases, and thus the rate at which water is pumped out increases. Since water is now being pumped out faster than it enters via the tap, the water level falls. The water level continues to fall until it returns to its previous steady-state level, where the rate at which water enters the tank matches the rate at which it leaves.

This is an example of feedback, because a change in the water level in the tank leads to a change in the pumping rate, and this then leads to a further change in the water level. Because the initial *increase* in the water level leads to an increase in the pumping rate, which then causes the water level to *decrease*, this type of feedback is called *negative feedback*. The important point about negative feedback is that any initial change causes an effect that counteracts that initial change, and so negative feedback helps to maintain a system in a state of balance.

(b) In the second example, the rate at which water enters the tank again initially matches the rate at which it is pumped out. When a bowl of water is added the level of the water increases, and thus the rate at which water is pumped out decreases. Since water is now being pumped out more slowly than it enters via the tap, the water level rises further. This causes the pumping rate to decrease even further, and so the water level continues to rise, until it spills over the top, and continues to overflow.

This is another example of feedback, since a change in the water level again leads to a change in pumping rate, and this leads to a further change in water level. However, this time the initial *increase* in water level leads to a decrease of pumping rate, and so the water level *increases* still further. Because the initial change and the further change that results from it are both in the same direction, this is an example of *positive feedback*. The important point about positive feedback is that it acts to accentuate any initial change.

You may be wondering how this relates to the feedback that you get from your tutor. Well, suppose that you produce a better-than-normal answer to a TMA question. Your tutor then gives you 'positive feedback' that highlights what you have done well and encourages you to repeat this in future TMAs, and as a result you

produce even better answers. Conversely, if you make a silly mistake in a TMA your tutor will give you 'negative feedback' on your performance, and this will hopefully act to counteract your lapse of concentration (or whatever was responsible for the mistake) so that your performance on the next TMA is restored to its normal level. Of course, the difference between your tutor and the water tank model is that your tutor gives positive feedback on good performance and negative feedback on poor performance, and these both act to improve your performance. A tutor who gave positive feedback on poor performance would make the performance get even worse!

Activity 7.1 again involved a model, and you might like to reflect on how the model was useful. In particular, did you find it easier to visualize positive and negative feedback using the model rather than using the GMST?

Activity 8.1

(a) For each reservoir, the rate of transfer of carbon is found from Equation 8.1.1:

$$\text{rate of transfer} = \frac{\text{mass of carbon in reservoir}}{\text{residence time}}$$

atmosphere:

$$\text{rate} = \frac{760 \times 10^{12}\ \text{kg C}}{3.6\ \text{y}} = 210 \times 10^{12}\ \text{kg C y}^{-1}$$

living things:

$$\text{rate} = \frac{560 \times 10^{12}\ \text{kg C}}{4.7\ \text{y}} = 120 \times 10^{12}\ \text{kg C y}^{-1}$$

surface ocean:

$$\text{rate} = \frac{1\ 000 \times 10^{12}\ \text{kg C}}{7.9\ \text{y}} = 130 \times 10^{12}\ \text{kg C y}^{-1}$$

soil:

$$\text{rate} = \frac{1\ 500 \times 10^{12}\ \text{kg C}}{25\ \text{y}} = 60 \times 10^{12}\ \text{kg C y}^{-1}$$

deep ocean:

$$\text{rate} = \frac{37\ 000 \times 10^{12}\ \text{kg C}}{1\ 000\ \text{y}} = 37 \times 10^{12}\ \text{kg C y}^{-1}$$

ocean sediment:

$$\text{rate} = \frac{3\ 000 \times 10^{12}\ \text{kg C}}{5\ 000\ \text{y}} = 0.60 \times 10^{12}\ \text{kg C y}^{-1}$$

rock:

$$\text{rate} = \frac{50\ 000\ 000 \times 10^{12}\ \text{kg C}}{200\ 000\ 000\ \text{y}} = 0.25 \times 10^{12}\ \text{kg C y}^{-1}$$

All of these numbers have been quoted to two significant figures.

Make sure that you have entered the correct values in the final column of Table 8.1. Note that since this column is headed 'Rate of transfer/10^{12} kg C y^{-1}', the atmosphere value, for example, would be entered simply as 210.

(b) The reservoirs in the biological subcycle are all smaller, and the rates of transfer are all larger, than in the geochemical subcycle.

Activity 8.2

Part I — at the start of Section 8.4

Figure 8.2.1 shows our flow diagram for the biological carbon cycle. You may have laid out your diagram in a different way, but you should have the same number of arrows entering and leaving each box, and they should be labelled with the same values as in Figure 8.2.1. For each box, the rates of transfer in and out are in balance. For example, for the atmosphere the rates (in the unit 10^{12} kg C y^{-1}) are:

rates in: $(60 + 60 + 90) = 210$

rates out: $(120 + 90) = 210$

You might have noticed that the rate in and the rate out here for the surface ocean do not match the transfer rate that you calculated in Activity 8.1. This is because we have not yet included substantial exchange rates with the deep ocean; these will be added later.

Part II — at the end of Section 8.4.4

There are no comments on this part.

Part III — at the end of Section 8.5.1

Figure 8.2.2 shows our flow diagram with the deep ocean reservoir added. The numbers entering and leaving the reservoir balance, 33 + 4 = 37, so this reservoir is in a steady state.

Part IV — at the end of Section 8.6.2

(a) Figure 8.2.3 shows our flow diagram with the ocean sediment and rock reservoirs added. These new reservoirs are in steady states, since the rates of transfer of carbon into and out of each of them are in balance. You might have noticed, however, that the addition to your diagram of the transfers to and from the rock reservoir appears to have put the atmosphere, the ocean and the soil reservoirs slightly out of balance. This is because the values for the transfers are each known to only one or two significant figures. For example, when we add the additional 0.05×10^{12} kg C y^{-1} from volcanic activity to the 210×10^{12} kg C y^{-1} that is transferred to the atmosphere reservoir, the result is still 210×10^{12} kg C y^{-1}, to two significant figures.

(b) As an example of calculating the residence time for a reservoir from the information in Figure 8.2.3, we'll consider the surface ocean. The mass of carbon in this reservoir is $1\ 000 \times 10^{12}$ kg C, as shown in Figure 8.2.3 and Table 8.1. The rate of transfer of carbon out of the reservoir is $(90 + 33 + 4) \times 10^{12}$ kg C y^{-1} = 127×10^{12} kg C y^{-1}. So using Equation 8.2.1, the residence time of carbon is

$$\frac{\text{mass of carbon in reservoir}}{\text{rate of transfer of carbon out of reservoir}}$$

$$= \frac{1000 \times 10^{12}\ \text{kg C}}{127 \times 10^{12}\ \text{kg C y}^{-1}}$$

$$= 7.9\ \text{y}$$

This agrees with the value of the residence time in Table 8.1. You may have calculated the residence times for other reservoirs, and your answers should agree with the values in Table 8.1.

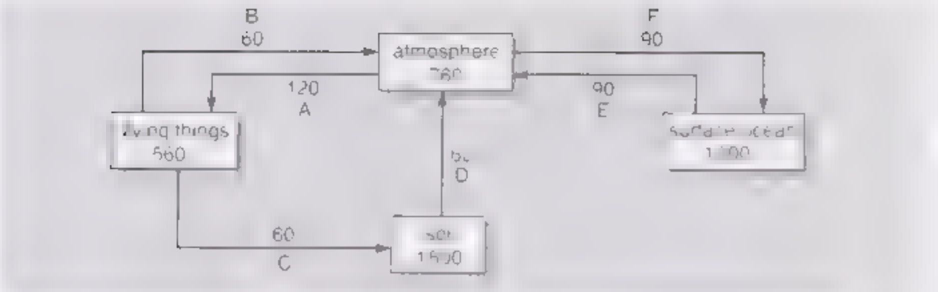


Figure 8.2.1 A flow diagram for the biological carbon cycle, the rates of transfer have the unit 10^{12} kg C y^{-1}, and the reservoir masses have the unit 10^{12} kg C.

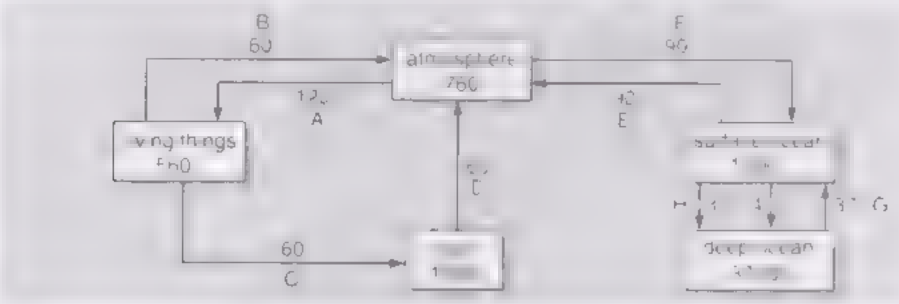


Figure 8.2.2 A flow diagram for the biological carbon cycle, with the deep ocean reservoir added; the rates of transfer have the unit 10^{12} kg C y^{-1}, and the reservoir masses have the unit 10^{12} kg C.

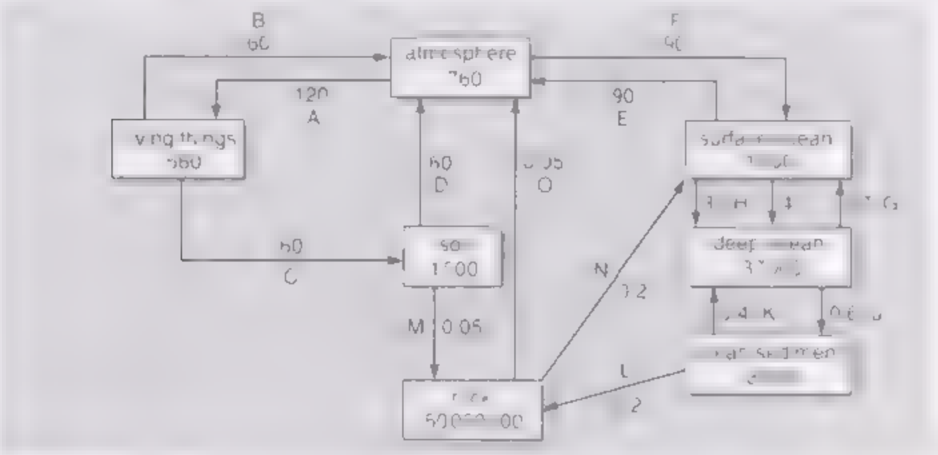


Figure 8.2.3 A flow diagram for the global carbon cycle; the rates of transfer have the unit 10^{12} kg C y^{-1}, and the reservoir masses have the unit 10^{12} kg C.

This completes your flow diagram for the seven reservoirs that we chose for our model of the global carbon cycle. In completing Activity 8.2 you have experienced two benefits of producing a flow diagram. Producing the diagram required you to interact with the text, and this should have helped you to understand the material. In addition, you have now summarized information from about ten pages of text into a single diagram

Note that though we expect you to remember the seven major reservoirs of the carbon cycle, and the processes by which carbon moves between the reservoirs, we do *not* expect you to remember the numerical data in Figure 8.2.3 or Figure 8.7.

Activity 8.3

(a) The middle column in Table 8.3.2 shows which arrow in Figure 8.7 corresponds to each process by which carbon is transferred between the reservoirs.

(b) Compare your answers with those listed in Table 8.3.2. You should have included the same points although your words will be different

You may have found this part of the activity difficult because some of the processes seem related. Activity 8.5 at the end of Section 8 will give you another opportunity to review these processes.

(Note that in Section 8 we have defined the processes merely in terms of their effect on the carbon cycle. You will meet many of the processes again in later blocks in different contexts.)

Table 8.3.2

Process	Arrow	Carbon transformation
atmospheric CO_2 dissolution	F	Atmospheric CO_2 dissolution is the process by which CO_2 from the atmosphere dissolves in surface seawater (and fresh water) and becomes dissolved carbon
biological pump	I	Through the biological pump, particulate carbon (both organic carbon and carbonate carbon) is transported from the surface ocean to the deep ocean.
decomposition	D	In decomposition organic carbon in dead organic matter is converted into CO_2 in the atmosphere (or dissolved carbon in water) by respiration of worms, bacteria, etc.
dissolution and respiration of sediment	K	Dissolution and respiration of sediment are the processes by which carbonate carbon sediments and organic carbon sediments, respectively, are transformed into dissolved carbon in the deep ocean.
leaf fall and death	C	Leaf fall and death is the main process by which living organic carbon stored in vegetation is transferred to dead organic carbon in the soil, either directly or via consumption by animals
CO_2 degassing	E	Through degassing, dissolved carbon in surface seawater (or fresh water) is released into the atmosphere as CO_2.
photosynthesis	A	Through photosynthesis CO_2 in the atmosphere (or dissolved in water) is converted into organic carbon in green plants
respiration	B	Respiration is the process by which organic carbon in living organic matter is converted into CO_2, releasing stored energy
rock formation (land)	M	Rock formation (land) is the process by which deep buried (mostly organic) carbon from undecomposed vegetation becomes lithified (converted into organic rock)
rock formation (ocean)	L	Rock formation (ocean) is the process by which organic carbon or carbonate in sediments is converted into organic sedimentary rock or carbonate rock.
sedimentation	J	Sedimentation is the process by which particulate carbon from the deep ocean is transferred to organic and carbonate sediments.
sinking	H	Through sinking, dissolved carbon in the surface ocean is transported into the deep ocean
upwelling	G	Upwelling is the process by which dissolved carbon is transferred from the deep ocean into the surface ocean
volcanism	O	Through volcanism, organic and carbonate carbon stored in rock is released to the atmosphere as CO_2.
weathering	N	Weathering is the process by which carbonate or organic carbon in rock is released, initially to streams and lakes, and from there to the surface ocean as dissolved carbon

Activity 8.4

(a) From Figure 8.9, the proportion of CO_2 in the atmosphere was 322 p.p.m. in 1968 and 356 p.p.m. in 1992. So the approximate increase in CO_2 from 1968 to 1992 is (356 p.p.m. − 322 p.p.m.) = 34 p.p.m. CO_2. (Don't worry if the values you read off the graph were slightly different from ours.)

(b) A 34 p.p.m. increase in 24 years is a mean annual increase of

$$\frac{34\ \text{p.p.m. } CO_2}{24\ \text{y}} = 1.4\ \text{p.p.m. } CO_2\ \text{y}^{-1}$$

(to 2 sig figs)

(c) You are told that 360 p.p.m. corresponds to 760×10^{12} kg C. Therefore 1 p.p.m. corresponds to

$$\left(\frac{760}{360}\right) \times 10^{12}\ \text{kg C}$$

Hence 1.4 p.p.m. corresponds to

$$1.4 \times \left(\frac{760}{360}\right) \times 10^{12}\ \text{kg C} = 3.0 \times 10^{12}\ \text{kg C}$$

(to 2 sig figs)

Therefore the measured annual increase of 1.4 p.p.m. $CO_2\,y^{-1}$ is equivalent to a global increase of 3.0×10^{12} kg C y^{-1} in the atmosphere.

(d) The rate of release from human activities, which is 7×10^{12} kg C y^{-1}, is over double the rate of increase of carbon in the atmosphere.

Activity 8.5

Your travels around the carbon cycle should have reinforced your understanding of the interconnected array of carbon reservoirs and of the processes that link them. As you have seen, carbon can move from many of these reservoirs directly into the atmosphere as carbon dioxide, where it affects the GMST via the greenhouse effect.

Some of the simplifying assumptions, regarding reservoirs and processes, that have been made in the version of the carbon cycle used in this DVD are listed below

1 The activity is concerned with transfer of carbon *between* reservoirs, and the program doesn't examine movements *within* a reservoir. So you can move the carbon atom from a rabbit to a fox (which happens in real life), and also from a fox to a rabbit (which doesn't happen) without any restriction, because both are part of the 'land consumers' reservoir

2 A number of biological processes have been lumped together under the heading of 'respiration'. Normally, the term respiration is used for the conversion of organic carbon (and oxygen) into carbon dioxide and water, with the release of energy. The carbon dioxide formed in this process becomes atmospheric carbon dioxide when respiration takes place on land, or dissolved carbon when respiration takes place under water. However, in this activity we have lumped together all of the processes that occur when organic carbon is consumed, including assimilation to become part of the biomass of the consumer and production of waste by the consumer, as well as 'normal' respiration.

3 The reservoirs of 'soil' and 'marine organic sediments' are assumed to be composed of dead organic carbon *and* the associated consumers (detritivores and decomposer organisms).

4 Dead organic matter always passes through living consumers (detritivores and decomposers) when it decomposes. However, in this activity you do not have to move the carbon atom through this extra stage of the decomposition process explicitly. You can move the carbon atom from a (live) animal or plant into the soil, where it would be in dead organic matter, and from there you can move the atom directly to other reservoirs by the respiration process. Respiration in this case corresponds to the biological processes of the decomposers and detritivores in the soil

5 Because the carbon in the soil reservoir is assumed to be organic carbon, it can move to fresh water when the soil is underwater by the respiration process (but not by dissolution). Any calcium carbonate in the soil is considered to be part of the carbonate rock reservoir: this material can pass to the fresh water reservoir by dissolution (but *not* by respiration)

6 The biological pump is not included as a separate process in this activity.

7 Carbonate rock can become dissolved carbon in fresh water by weathering or dissolution, and carbonate sediments can become dissolved carbon in the deep sea by dissolution. However, neither carbonate rock nor carbonate sediments dissolve in the surface sea (in reality very little does so). Also, carbonate rock does not dissolve in the deep sea because it is overlain by sediments and is therefore not in contact with deep ocean water

Activity 9.1

Our summary is in the paragraph following Activity 9.1 in Block 2. You probably found it more convenient to present your summary as a list of points.

You might have found that your memory of a section reflected some aspect that made a particular impression on you, for example a DVD-video or multimedia activity, rather than the main message of the section. This shows the importance of having good summary notes that you can readily refer to.

Activity 9.2

In this activity you should have.

- explored the sensitivity of the GMST with respect to changes in various factors that determine the GMST, with and without coupling between the factors;
- used a second climate model to explore variations of mean surface temperature with latitude, and with season

You should now return to Block 2 at Section 9.1.2.

Activity 9.3

The dust would not affect the solar luminosity because it cannot affect the power source of the Sun. This power source is deep inside the Sun, beyond the effect of dust between the Sun and the Earth

Dust absorbs and reflects solar radiation and thus reduces the solar power reaching the Earth. Therefore the solar constant would be reduced

If the solar constant were reduced then the dominant source of energy for the Earth's surface would have been decreased and thus the GMST would fall. Figure 9.3.1 illustrates the change in GMST. (*93 words*)

(Note that the dust is *outside* the Earth's atmosphere, so there is no possibility that absorption by the dust will raise the temperature of the atmosphere and thus increase the power of atmospheric radiation at the Earth's surface.)

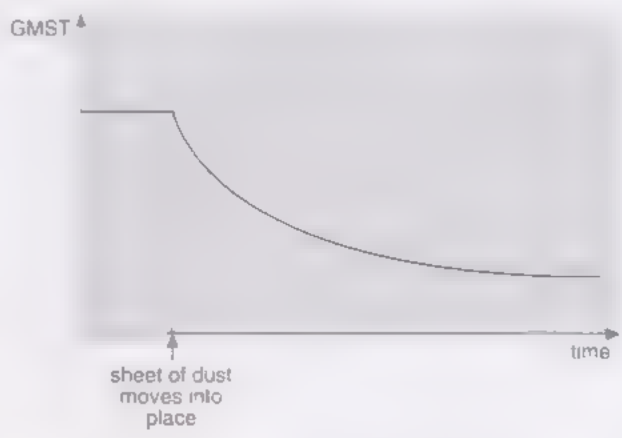


Figure 9.3.1 The decrease in GMST if the solar constant is reduced. (Compare this with Block 2 Figure 4.4c.)

Scientists often pose themselves questions that begin 'what if ...?'. In this activity, the question was

effectively 'what would happen if a dust cloud ...?', and your task was to predict the consequences. Having predicted the consequences for the solar constant and the GMST, you would then be able to describe whether observed changes in either of these quantities were consistent with the arrival of a sheet of dust.

Activity 9.4

The source of material is Sections 9.2.1 and 9.2.2. One possible summary is given below.

> In the distant past there might have been much larger amounts of CO_2 in the atmosphere than there are today. This would have raised the GMST considerably above the value it would otherwise have had, and prevented the Earth's surface from freezing. This compensation operated over a long time-scale. On the shorter time-scale of the last 150 years or so, the much smaller increase in the CO_2 content from 285 p.p.m. to 360 p.p.m. seems to have been the main cause of the 0.7 °C or so rise in GMST since 1850.
>
> Over the 4 600 Ma of Earth history the solar luminosity has increased fairly steadily from about 70% of its present value. Such a large change would have had a large effect on the GMST, unless differences in other factors, such as CO_2 content and cloud cover, offset the effect of low luminosity. Smaller changes of about 0.5% in solar luminosity that occur on a short time-scale seem to have contributed significantly to changes of up to about 1 °C in the GMST. *(182 words)*

Your summary will inevitably be different from this one in small details, but make sure that you have included all of the key points and that you have not used substantially more than 200 words.

It is well worth developing the habit of checking a written account to make sure that it covers the appropriate ground and is logically organized. Note how this summary has been split into paragraphs, each covering one of the important areas. Note also that numbers and symbols are used freely, since this is a scientific account; they are generally much easier to read than their equivalent words.

Activity 9.5

(a) A mathematical model consists of a set of mathematical equations. When the equations are worked through they yield the values of quantities in which we are interested. A scale model is an object that has a different size from the real thing and it might be made of different materials. All models are simplified representations of the real world, that aid understanding by focusing on some particular aspect of reality. *(70 words)*

(b) (i) Simplifications made in a climate model can include

- treating the atmosphere as one entity, rather than dividing it up into a suitable number of horizontal levels;
- ignoring latitude or longitude variations across the Earth's surface, or having too few divisions across the Earth's surface,
- using simplified equations to represent important processes.

(ii) Simplifications made in a scale model of the Earth (a globe) include

- ignoring the internal structure and composition of the Earth;
- ignoring the detailed shape of the Earth's surface;
- showing only the largest details of the shape of the Earth's surface.

Activity 10.1

Compare your explanations with ours that follow to make sure that you have included the same main points. Of course, you are likely to have presented them in a different way. Note how the answer starts with an introductory sentence saying which two activities have increased CO_2 in the atmosphere so that the reader knows what will be discussed. The following two paragraphs then each discuss one of the activities.

> Both burning fossil fuel and clearing forests have caused the level of CO_2 in the atmosphere to increase.
>
> CO_2 is 'captured' from the atmosphere during photosynthesis and incorporated into plant tissues. Respiration and decomposition of these tissues usually results in most of this CO_2 being released back into the atmosphere quite quickly. However, as a result of the environmental conditions that prevailed for millions of years, many millions of years ago, huge amounts of carbon became 'locked away' beneath the Earth's surface as fossil fuel. Burning this fuel causes CO_2 to be released back into the atmosphere. Its atmospheric level is likely to have risen because we've burnt a large amount of this fuel in just a few hundred years.
>
> Although forests have been cleared for many thousands of years, the pace of clearance has increased in recent decades. The immediate effect of forest clearance is essentially the same as that of burning fossil fuel. *(159 words)*

Deforestation is mentioned only briefly in Section 8, so it is worth adding a few extra comments here. Wood not considered commercially valuable is either burnt immediately or allowed to decay rapidly. Most of the carbon in the wood that is removed to make paper, furniture, etc. probably also returns quite quickly to the atmosphere as CO_2. However, this is not the only effect of forest clearance. Mature forest trees are often replaced by crops or else short-lived 'scrubby' vegetation is allowed to take over. If the forests had been replanted, the young trees would have re-captured much of the CO_2 as they grew and large amounts of carbon would become stored in their wood for perhaps hundreds of years. Instead, a smaller amount of carbon is cycled rapidly between the atmosphere and the short-lived plants. Extensive forests, especially if they are young and/or additional to those already in existence, could help to counter the effects of burning fossil fuel.

Activity 10.2

Achievements of climate models:

- good agreement for overall climate in the recent past
- particularly good agreement for GMST in the recent past

Shortcomings of climate models

- poorer agreement over other aspects of climate, e.g. precipitation
- poor predictions for climate on a regional basis
- not good for describing climate in the distant past — too much uncertainty

These notes could be structured to give a piece of writing something like the following

> The present generation of climate models account quite well for many aspects of the Earth's overall climate in the recent past, in particular the GMST. There is poorer agreement between the models and other aspects of climate, such as precipitation. Another major weakness is that the models are not particularly good at predicting climate on a regional basis. In the distant past there is uncertainty about many of the factors that control climate, and about the climates themselves. *(78 words)*

Activity 10.3

(a) Two student answers are given below.

Student A

Higher GMST would alter the distribution of wildlife.

Agriculture would be affected and there would be more pests.

It would rain more

Some buildings would need air conditioning.

Transport could be affected.

Student B

1 Introduction — the situation is not as simple as it seems

2 Higher GMST could result in other climate changes too, e.g. increased rates of precipitation.

3 Higher GMST would lead to the melting of ice-caps with a consequent rise in sea-levels. Low-lying areas would be flooded

4 There could be major effects on agriculture.

5 There could be more problems with pests and diseases

6 There could be a need for air conditioning, etc. in some countries that have a moderate climate at present

7 Conclusion — there would be winners and losers.

Both of the answers contain most of the points given in the summary of Section 10. Student B has missed out the effects on transport and has not explained about the distribution of wildlife. However, this is still the better answer. Student A has missed out the effects on sea-level and although the order is not illogical, the student has not thought clearly about how to put the points together to form a letter. In contrast, Student B has taken up the correspondent's claim of a balmy climate for the UK and immediately answered by discussing other likely climate changes and (presumably) the fact that large areas of the UK would be submerged. Student B has then discussed effects on agriculture and housing, before concluding that there would be losers as well as winners. Student A's plan does not mention the need for an introduction and conclusion. Student B has clearly extracted information from the text and then spent some time in ordering it to give a logical flow and this plan would make a powerful letter.

(b) The letter and the book section should both be written in a clear and logical way, and should include an introduction and a conclusion. They should both deal with the topic asked for, be factually correct and not go over the required word limit. They should be correct in their use of grammar and spelling, and avoid jargon that the readers would not understand The main difference between the letter and the book section is that the letter needs to be persuasive and to argue a case, whereas the book is required to be purely factual. We will be distinguishing between these and other writing styles as the course progresses, and *SGSG* Chapter 9, Section 2, discusses different styles of scientific writing For the time being, it is more important that you have a thorough grasp of the ground rules and that you can write in a logical way. There is no point in being persuasive in a letter if you are factually wrong, and the impact of your letter would be lost if you made major grammatical errors or did not write in a logical order.

Note how we have structured the comparison of the two forms of writing. We first discussed the similarities in terms of '*both* X and Y ...'. Then we described the differences in terms of 'X is ... *whereas* Y is ...'. This makes the comparison much clearer than first describing the features of one item (X) and then the other (Y).

Activity 11.1

(a) Block 2 has introduced a large number of bold terms, many of which may have been new to you, and there will inevitably be some that you are less sure about than others. Among the strategies that you may have adopted while studying the block are using the index to find the place where a term is explained (the entry in bold is the best one to try first), and using the Glossary to check on the meaning of terms. It's a good idea to have the Glossary close at hand for this purpose as you study. One strategy that some students use to help them to remember new terms is to produce their own glossary; writing out an explanation of a new term in your own words can be a good way of reinforcing the meaning, and glancing at your list of terms at intervals as you work through the block then gives further reinforcement. In later blocks we shall introduce a number of activities that involve producing your own glossary.

Most of your problem areas might be related to one or two sections. For example, perhaps you found the particle model and the concept of atoms and molecules a difficult area, or maybe you haven't got to grips with the complexity of the carbon cycle. If this is the case, then spending a bit more time on the appropriate section(s) could be helpful. Alternatively, it might be that your difficulties arise with particular types of material, such as areas that involve mathematics, or diagrams, or the use of models. Identifying areas that you might have found more difficult means that you can spend some time working on questions and activities related to these areas, or reading related sections of *SGSG*, and you will be able to plan to devote more time to similar material in later blocks.

What follows are notes on this part of the activity made by a student, with comments on the student's notes from a tutor in italics

Doing well

- Possible consequences of a rise in the Earth's surface temperature. I was just reading, but I was particularly interested in it because I saw a programme about it the other day
- Carbon cycle — producing the diagram helped a lot here, I felt involved

When you are interested in something, you learn much better (and don't notice time flying by) Also, if you're linking new information to things you already know about, it is much easier to fit the new bits in.

Producing a diagram forces you to think about the text You may be able to make diagrams for yourself to help you learn.

Not so good?

- Energy and power, because my maths isn't good. In fact, every time I came to some maths, I found it hard I found some bits in SGSG that helped, but I didn't really have time to work on them properly, but then I went to a tutorial, and met Chris, and now I phone Chris when I'm stuck. I suppose I should do more work on the basics, but there isn't time It would be a good thing to work on in the run up to the course, and if I had my time again, I'd do more maths

There are two strategies here that help when you're getting stuck: another source of information, and collaboration. Some students choose courses together for years because they find it so valuable to be able to talk over the ideas with friends. You'll find that you get used to working with the maths, just as you once got used to speaking English, and by the end of the course, you'll wonder what the problem was

- The water cycle. I got bogged down in lots of information, and couldn't visualize positive and negative feedback. Tried making diagrams, but in the end just moved on.

Two more excellent ways of handling difficulties here, making diagrams and moving on to something new. It would be a good idea to keep a note of strategies that work for you when you get bogged down, so that you are aware of what you might try another time

(b) By answering the questions you get an instant assessment of whether you have understood the main points, but doing the questions also acts as reinforcement of these points. The summarizing activities serve a similar function; picking out the main points of a section again requires you to understand what you have read, and writing them down will help you to remember them. Highlighting and notes are a useful preliminary step to summarizing, and quickly skimming through your highlighted points and notes at the end of a study session, and at the beginning of the next session, will help to pull the main ideas together.

Here are some more student notes and tutor comments

- I take time to do the questions and activities because these must be the things that are important. I sometimes begin by looking at these, so that when I read the text, I know what I'm looking for.

The authors of the course will make sure that the questions and activities cover the most important points Also, you'll find that the same kinds of thing come up in the assignments as in the questions and activities.

Also when you finish a task, think about how you did it, and maybe think about how you could do it better. If you do this, you'll find that tasks fit into families, and thinking about how you do them helps you to improve your performance on other similar tasks

- To begin with I used lots of highlighter, but I've cut it down a lot. I'm finding making notes alongside the text is more useful. I've tried making summaries, but it seems to take a long time to achieve very little, and so I've given up on them

Whether you highlight, make notes on the text or write summaries, the important thing is that you are studying the material in an interactive way. Most people find that they learn better if they work over the material more than once, especially if they put it into their own words Remember that notes can also be useful for later reference when you want to find something again, or revise what you've learned SGSG discusses note-taking (Section 5 of Chapter 2) if you want to think about this some more

(c) Most students devise their own personal techniques that they find help them to learn, in addition to using techniques suggested in the course. It is worth discussing techniques that you find useful with other students, and seeing if you can pick up any useful suggestions from them There are as many ways of studying as there are students, and you should experiment with new ways of learning as well as continuing to use the techniques that you have already found to be effective. Here are a few points that one student noted down, again with tutor comments added in italic

- At first I read straight through, taking everything as it came. Now I look ahead to summaries and questions before I begin reading and see what I'll need to learn. This helps me to work out what I should concentrate on, and what I can skip or do quickly so I can keep up to schedule.

This is a very good way to approach your learning You could also ask yourself questions what do you want to find out about in this section? Some experienced OU students say they begin by reading the assignment questions

- Don't spend too much time on one area: I've stuck to this If you spend too long, you sometimes make things more complicated than they really are.
- When your assignment comes back, read over the tutor feedback, think about what it says, and file it for later reference

It's the thinking that's important, think about how your tutor's comments can help you to improve your next TMA

(d) Finding a bit of time to follow up any bold terms or objectives that you are unsure about is a useful way to round off your study of this block (and future blocks in the course). However, you should not do this at the expense of delaying your start on Block 3 at the scheduled time. Do not hesitate to contact your tutor if you are finding difficulty in learning the course material

Objectives for Block 2

The objectives state what you should understand and what you should be able to do after studying the block.

The numbers of the questions and activities that test each objective are given in italics. In the margin next to some objectives are references to sources of extra support, namely the Block 1 DVD material and *The Sciences Good Study Guide* (*SGSG*). References to the latter give the chapter and section number or Maths Help (MH) section number.

Science content

1 Explain the meaning of, and use correctly, all of the terms printed in **bold** in the text.

2 Outline the procedures for measuring and calculating mean surface temperatures, and describe sources of uncertainty in these values. (*Questions 2.3–2.6 and 10.1*)

3 Describe some of the landforms produced by glacial action, and how these relate to past temperatures. (*Questions 3.2, 3.7 and 10 1*)

4 State and apply the principles of using fossils to infer past climates and temperatures. (*Questions 3.3–3.7 and 10.1*)

5 Outline the amounts by which the GMST has changed over geological and historical time (*Questions 3.5, 3.6 and 10.4*)

6 Recall that electromagnetic radiation (which includes light, ultraviolet radiation and infrared radiation) is a form of energy, and that absorption of energy can lead to an increase in temperature. (*Questions 4.1 and 5.1; Activities 4.2 and 5 1*)

7 Explain what is meant by a steady state, and apply the concept of a steady state to the GMST. (*Questions 5.1 and 5.7; Activities 4.1 and 4.2*)

8 Outline the main factors that determine the Earth's surface temperature, the way in which they operate, and the sorts of change that they produce in the GMST. (*Questions 5.2–5.7, 9.1–9 4 and 10 2, Activities 4.1, 4.2, 5.1–5.3 and 9.2*)

9 Apply a simple particle model to explain (a) the differences between gases, solids and liquids, (b) changes of state and (c) the pressure of a gas. (*Questions 6 1–6 3, 6.7 and 6 8, Activities 6.3 and 6 5*)

10 Apply a simple model based on atoms and molecules to explain the differences between elements, mixtures and compounds, and interpret simple molecular structures of compounds. (*Questions 6.9–6.11*)

11 Describe the composition and properties of the Earth's atmosphere. (*Questions 6.3, 6 6, 6.13 and 6 15; Activities 6.1, 6 2, 6 6 and 6 7*)

12 Recall that atoms are neither created nor destroyed in a chemical reaction, and use this fact to balance simple chemical equations. (*Questions 6 14 and 6 16*)

13 Explain what is meant by the greenhouse effect, and relate the Earth's greenhouse effect to the composition of the atmosphere. (*Questions 6 17 and 6 18*)

14 Describe the main features of the Earth's hydrological cycle, including the general notions of reservoirs and rates of transfer between reservoirs. (*Questions 7.1–7 7; Activity 2.1*)

15 Explain what is meant by positive and negative feedback, and apply these concepts in a variety of situations. (*Question 9 2; Activity 7.1*)

16 Describe the Earth's carbon cycle, including the main reservoirs and transfer processes and the factors that cause changes in the atmospheric CO_2 content. (*Questions 8.1–8.5; Activities 8 1–8.5 and 10.1*)

17 Outline why the Earth's mean surface temperature has varied in the past, and why the causes of this variation are not fully understood. (*Activities 9.2, 9.4 and 10 2*)

18 Outline possible future changes in atmospheric CO_2 and in climate. (*Questions 10 3 and 10 4*)

19 Outline the possible effects of a temperature rise on life on Earth. (*Questions 1.1, 10.5 and 10 6; Activity 10 3*)

Science skills

SGSG 8.1&2 — 20 Give examples of the use of models in science and the use of analogies to help to understand a concept. (*Activities 4.1, 9.5 and 10.2*)

21 Carry out a simple investigation, including designing and setting up equipment from a general specification, making measurements, recording data in tables, analysing data, comparing the results with published measurements and stating a conclusion for the investigation. (*Activities 2.1 and 5.1*)

Communicating science skills

SGSG 3.2, 3:3.2, and 5:5.1 — 22 Extract information from tables, graphs, histograms, pie-charts and maps, and describe this information in words. (*Questions 2.1, 2.5, 3.4–3.6, 5.2, 6.6, 6.12, 7.1–7.3, 8.3–8.5, 9.2 and 10.3; Activities 6.6 and 8.1*)

SGSG MH10(parts) — 23 Plot a graph on prepared axes. (*Activity 5.1*)

SGSG 3.1.1 — 24 Interpret a flow diagram, and construct a flow diagram from information that is provided. (*Question 5.7; Activities 5.2, 5.3 and 8.2*)

SGSG 9.3 — 25 Produce a summary of a section of text, or of a topic discussed in a number of sections, in the form of a list of points or a piece of prose of a specified length (up to 200 words). (*Question 10.1; Activities 3.1, 4.2, 6.1, 6.7, 9.1, 9.4, 10.1 and 10.2*)

SGSG 9.3 — 26 Write an explanation or description in your own words of a scientific concept or topic. (*Questions 3.2, 5.4–5.6, 5.12, 6.2, 6.3, 6.10, 7.7, 9.2, 10.5 and 10.6; Activities 4.1, 7.1 and 8.3*)

SGSG 3:4 — 27 Use diagrams and/or graphs as part of a written account. (*Question 6.8; Activity 4.1*)

SGSG 9.5.3 — 28 Produce a plan for a piece of writing that lists all the main points in a logical order. (*Activity 10.3*)

Mathematical skills

SGSG MH6 — 29 Perform calculations to an appropriate number of significant figures. (*Questions 2.2–2.4, 3.1, 3.8, 3.9 and all subsequent calculations*)

30 Calculate a mean value. (*Questions 2.3, 2.4 and 7.2; Activity 2.1*)

SGSG 5:4, Block 1 DVD 'Practising maths skills' — 31 State the SI units (and their prefixes) of speed, energy, power, and number density, and the non-SI units of geological time (ka, Ma, Ga), pressure (bar) and precipitation rate (mm y^{-1}). Use units correctly in calculations and when quoting values of measured quantities. (*Questions 3.1, 3.8, 3.9, 4.1 and 4.2*)

SGSG MH3–5, Block 1 DVD 'Practising maths skills' — 32 Convert between fractions, decimals, percentages and parts per million. (*Questions 5.3, 6.6, 6.9, 6.12 and 8.1*)

33 Use a 'word equation' in a calculation. (*Questions 2.3, 2.4 and 4.2*)

SGSG MH8, Block 1 DVD 'Practising maths skills' — 34 Perform calculations involving powers of ten. (*Questions 3.8, 3.9, 4.2, 6.4–6.6, 8.1 and 8.2; Activities 8.1, 8.2 and 8.4*)

SGSG MH2, Block 1 DVD 'Handling negative numbers' — 35 Perform calculations involving negative numbers. (*Questions 6.4–6.6, 8.1 and 8.2; Activities 8.1, 8.2 and 8.4*)

Effective learning skills

SGSG 1:3, 1:4 — 36 Draw up, implement, and revise, a study plan for a four-week period, and review it at the end of the period. (*Activities 1.1, 5.4 and 11.1*)

SGSG 2·5 — 37 Use a variety of techniques for studying text, including constructing 'spray diagrams', and reflect on the usefulness of each technique. (*Activities 6.3 and 11.1*)

SGSG 6:3.2; 7:3.7 — 38 Use appropriate techniques for studying materials presented as DVD-video (*Activities 6.2, 6.4 and 6.6*) and as DVD-multimedia (*Activities 8.5 and 9.2*).

39 Use the list of objectives and the bold terms in the block to identify areas where more work may be needed, and use the Glossary, questions, activities and *SGSG* to help resolve any difficulties. (*Activity 11.1*)

Appendix Citing source materials in TMAs and the end-of-course assessment and plagiarism

1 Bibliographies and reference lists

If you look at an article in a scientific journal, or a science textbook, you will find either a bibliography or a reference list, indicating the source material that the author has used when writing the text. A bibliography is simply a list of all the sources used in the piece of writing. The list is usually found at the end of the article or book but you may see separate bibliographies at the end of each chapter. A reference list is similar, but each item in the reference list has been explicitly referred to somewhere in the text. Reference lists are generally much more useful than bibliographies as they pinpoint the page on which a reference may be found. We will be encouraging you to use reference lists in all of your TMA and ECA long-account answers.

Citing your sources is very important because to pass off the work of other people as though it were your own is known as *plagiarism*, which is a serious academic offence. Plagiarism includes copying passages from your course materials word for word, or very close paraphrasing of these materials (see Section 5.2 of the *Course Guide*) It is important, therefore, that you get into the habit from the beginning of acknowledging the sources of the material you use to prepare your TMAs. If you have any remaining worries after you have read this appendix about what constitutes plagiarism you should talk to your tutor, who will advise you.

The chances are that the only materials that you will be using to answer TMA 02 are those supplied as part of Block 2, and this is likely to be true of all of the TMAs in S103. You certainly don't need to look further afield than the course materials in order to obtain full marks for your TMAs, and we don't expect you to. Nonetheless, the issues of global warming and its side-effects discussed in Block 2 are topical and you may decide you'd like to include something you came across in a book, a popular science journal such as the *New Scientist*, or even a newspaper science column. At the end of the course, when you are studying Block 12 and completing the end-of-course assessment, you will be using a much wider range of source material. So, before you begin writing your TMAs it is important that you understand how to reference any source materials that you use, and how to handle direct quotations from them, and so avoid the pitfalls of plagiarism.

Referencing may look a complicated procedure, but don't be daunted by it. If you get into the habit of doing it from the beginning, it will be second nature to you by the time you reach the end of the course. It may also help you to achieve more marks as your tutor may be able to give you credit for information that you include from outside the course (provided it is relevant and factually accurate), and you will have a record of where you found your information when you look at the teaching feedback from your tutor.

2 Referencing material within your written text

When you want to reference something in your written text (for example, a specific piece of information you have taken from a Block, or a diagram you have copied, or an argument you are citing), you should include the reference in your text at the point where you use the material. For example, imagine you had read page 80 of Block 2, and from the information there, you decide you want to include the following sentence in your text: 'At the top of Mount Everest the air pressure is 0.28 bar'. You need to tell the reader where you got the information, immediately after you have written that sentence. There are two methods for doing this.

Method A

You could use a superscript number which refers to the full reference given in your reference list. Thus, your sentence would look like this:

> At the top of Mount Everest the air pressure is 0.28 bar[1].

and in your reference list at the end of your account, you would give the following:

1 Blake, S., Dise, N., Jones B., Murphy, P. and Taylor, P. (1998) S103 *Discovering Science*. Block 2: *A temperate Earth?* The Open University, Milton Keynes, p. 80.

The precise formatting of the reference is dealt with in Section 2.1 (below), but the thing to note here is that a '1' is used because it is first reference (or 'citation') used. The second reference would use '2', and so on. If you refer to this material again later on in your text, you do not need to enter the same reference again in the reference list, you simply use the superscript '1' again.

Method B

You may prefer to use a method that quotes the surnames of the authors and the year of publication within your text. In this case, you could use 'Blake, Dise, Jones, Murphy and Taylor, 1998', although for brevity, if you have three or more authors, it is usual to change this to 'Blake et al., 1998' (et al. is short for the Latin phrase 'et alia', meaning 'and others'). It is also usual to put this citation in parentheses. Thus, your sentence would look like this

> At the top of Mount Everest the air pressure is 0.28 bar (Blake et al., 1998).

and in your reference list at the end of your account, you would give the following:

Blake, S., Dise, N., Jones B., Murphy, P. and Taylor, P., (1998) S103 *Discovering Science*. Block 2: *A temperate Earth?* The Open University, Milton Keynes, p. 80.

Note that, in method B, you do *not* number the items in your reference list; you should list them in alphabetical order by the surname of the first author.

At first glance method A looks simpler and shorter. However using method B does tend to make it easier track where your information is coming from when you change or move text around (cut and paste) or if you insert extra references within your text (if you used method A you would have to re-number all your references). It is probably fair to say that the choice of most scientists is to use method B, although some leading scientific journals do use method A to save space.

You can use the name of the authors directly when referring to source material. For example you might say, 'Blake et al. (1998) state that the air pressure at the top of Mount Everest is 0.28 bar', or else, 'Blake et al.[1] state that the air pressure at the top of Mount Everest is 0.28 bar', depending of your method used in your reference list.

2.1 Formatting your references

We give here a guide to the formatting of references. If it looks complicated, the examples often show clearly what we mean. Note that 'p.' is used as the abbreviation for 'page' (where a single page is cited) and 'pp.' is short for 'pages' (where more than one page is cited)

In general, references in the list at the end of your account should include:

- The *surname(s) of the author(s)* followed by the *initials*: keep the names in the order shown on the work, which may not necessarily be alphabetical order;
- The year of publication

What happens next depends on the type of source.

(i) If the source is the S103 course materials written by OU staff, then you should give

- The *course code and title, and the block title*: these titles are shown conventionally in italics, but if you hand-write your TMAs and/or your ECA then you should underline the titles instead.
- The *publisher and place of publication*: for most OU-authored course materials the publisher is 'The Open University' and the place of publication is 'Milton Keynes';
- The page number(s) on which the information appears.

Examples

Bradshaw, K., McGarvie, D., Palmer, D., Rogers, N., Sheldon, P. and Webb, P. (1998) S103 *Discovering Science*. Block 10: *Earth and life through time*. The Open University, Milton Keynes, pp. 96-106.

Jones, B., Ridge. I., and Wright, I. (1998) S103 *Discovering Science*. Study File for Block 12: *Life in the Universe*. The Open University, Milton Keynes, p. 4.

Remember that figures that have been copied from a Block should also be referenced. If you have copied a figure, but altered it for your purposes, it is usual to say in the figure caption text, e.g. 'Adapted from Figure 5.14 in Blake et al. (1998)'.

(ii) If the source is an academic journal, newspaper or magazine, then you should give:

- The *title of the article*, in quotation marks;
- The *name of the journal, newspaper or magazine* (in italics), followed by the *volume number* (or the *date* on which the newspaper or magazine appeared): the volumes of some journals are published in several parts each year, in which case you should also give the part number;
- The page number(s) on which the article appears.

Example

Grady, M. and Wright, I. (1996) 'Life on Mars?' *Astronomy Now*, 10(10), pp. 39-42

(iii) If the source is a book, then you should give:

- The *title* (in italics, or underlined), the *publisher* and (if known) the *place of publication*, in the same way that you reference OU-written course materials.

(iv) If the source is a chapter or an article in a book that has been edited by someone else, then you should give:

- The title of the chapter (or article), in plain type (not underlined) and in quotation marks;
- The *names of the editor(s)* followed by the abbreviation 'ed.' (for editor) or 'eds' (for editors);
- The *title of the book* (in italics, or underlined), the *publisher* and the *place of publication*, if known;
- The *page numbers* occupied by the chapter or article in the book.

Example

Oro, J., Squyres, S. W., Reynolds, R. T. and Mills, T. M. (1992) 'Europa: prospects for an ocean and exobiological implications', in Carle, G. C., Schwartz, D.E. and Huntingdon, J. L. (eds) *Exobiology in Solar System Exploration*, NASA Special Publication 512, pp. 103-125.

In this example, the place of publication isn't known.

(v) Referencing a website: you may come across something that is relevant to your TMA or your ECA when you are using the Internet. Remember that *to use material from a website without proper acknowledgement counts as plagiarism*. It is also important to bear in mind that anyone can set up a website, whereas articles in journals have been refereed in order to guarantee the validity of their content. Some websites contain information that has been properly researched, but others have not and so may contain misinformation. When referencing a website you *must* give sufficient detail for the person who is marking your TMA or your ECA to be able to pin-point the source easily and rapidly, so that its accuracy can be checked. You should cite the date that the website was last updated. If you cannot find this, then you should cite the date on which you accessed the website.

Example

University of East Anglia Climate Research Unit. www.cru.uea.ac.uk/cru/info/ '1. Global temperature record'. (accessed 12 October 2004)

2.1 Example text

You may feel that you have already grasped the principles that we have explained, but we all know that an example is the best way of helping you to see how these methods of referencing operate in practice.

Imagine you are writing an account of the origin of life on Earth. You might have the following text in your account, referenced using method A.

> The Earth is believed to have originated around 4 600 Ma ago[1] and the evidence from carbon isotope ratios of sedimentary rocks from the Isua formation, Greenland, suggests that living organisms had already evolved by 3 800 Ma ago[2]. However, whether the first life-form originated in some kind of 'primordial soup', or on mineral surfaces such as the surfaces of clay minerals[3] or even in the vicinity of deep oceanic hydrothermal vents[4], is open to debate.

Your reference list, based solely on this paragraph, would read in numerical order as follows:

1 Jones, B., Ridge, I. and Wright, I. (1998) S103 *Discovering Science*. Study File for Block 12: *Life in the Universe*. The Open University, Milton Keynes, p. 4.

2 Woese, C. R. (1984) 'The origin of life', Carolina Biology Readers series, series editor J. J. Head, pp. 15-19.

3 Anon. (1996) 'Nature's feet of clay', *Chemistry in Britain*, June, p. 13.

4 Oro, J., Squyres, S. W., Reynolds, R. T. and Mills, T. N. (1992) 'Europa: prospects for an ocean and exobiological implications', in Carle, G. C., Schwartz, D. E. and Huntingdon, J. L. (eds) *Exobiology in Solar System Exploration*, NASA Special Publication 512, pp. 103-125.

Alternatively, you might have the same text in your account, referenced using method B:

> The Earth is believed to have originated around 4 600 Ma ago (Jones et al., 1998) and the evidence from carbon isotope ratios of sedimentary rocks from the Isua formation, Greenland, suggests that living organisms had already evolved by 3 800 Ma ago (Woese, 1984). However, whether the first life-form originated in some kind of 'primordial soup', or on mineral surfaces such as the surfaces of clay minerals (Anon., 1996)* or even in the vicinity of deep oceanic hydrothermal vents (Oro et al., 1992), is open to debate.

Your reference list, based solely on this paragraph, would read in alphabetical order as follows:

Anon. (1996) 'Nature's feet of clay', *Chemistry in Britain*, June, p.13.

Jones, B., Ridge, I. and Wright, I. (1998) S103 *Discovering Science*. Study File for Block 12: *Life in the Universe*. The Open University, Milton Keynes, p. 4.

Oro, J., Squyres, S. W., Reynolds, R. T. and Mills, T. N. (1992) 'Europa: prospects for an ocean and exobiological implications', in Carle, G. C., Schwartz, D. E. and Huntingdon, J. L. (eds) *Exobiology in Solar System Exploration*, NASA Special Publication 512, pp. 103-125.

Woese, C. R. (1984) 'The origin of life', Carolina Biology Readers series, series editor J. J. Head, pp. 15-19.

3 Quoting

When you write an account, your tutor will want to know that you have really understood the original text that we have asked you to read. For this reason, you should always try to express your understanding by using your own words. However, very occasionally you may wish to quote the original words of an article, *verbatim*, because what the author has said is either expressed so eloquently, or is so characteristic of the person who wrote it, that its impact would be lost if you put it into your own words. But before you do this, you should always ask yourself whether the direct quotation is really

* Anon. is an abbreviation of anonymous, implying that the name of the author of the article is not known.

justified, or whether you are trying to avoid using your own words because you don't really understand what the author is saying!

If you decide it *is* justified, then you should signal the beginning and end of the quotation using quotation marks ('…'), and cite the quotation as a reference.

Example

Imagine that you are concluding an account centred on the importance of water for the successful evolution of life on Earth. You might think it appropriate to end with an elegant and eloquent quotation from an article by Christopher Chyba:

> Chyba (1990) has commented on the way in which the oceans have inspired instinctive feelings of wonder in humankind: 'It is as though an inchoate understanding of our origins visited our minds even before the theory of evolution taught us that our beginnings lay in the sea.'

You would then need to include the details of the article by Chyba in your reference list.

However, you should also be aware that, even if you have cited the sources of your information, it is not acceptable to copy large chunks word for word from *any* source (including the course materials) into your TMA or ECA answer. This would constitute plagiarism.

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